Instruments

THE MAGAZINE OF MEASUREMENT
INSPECTION · TESTING · CONTROL

Including the

JOURNAL OF THE INSTRUMENT SOCIETY OF AMERICA

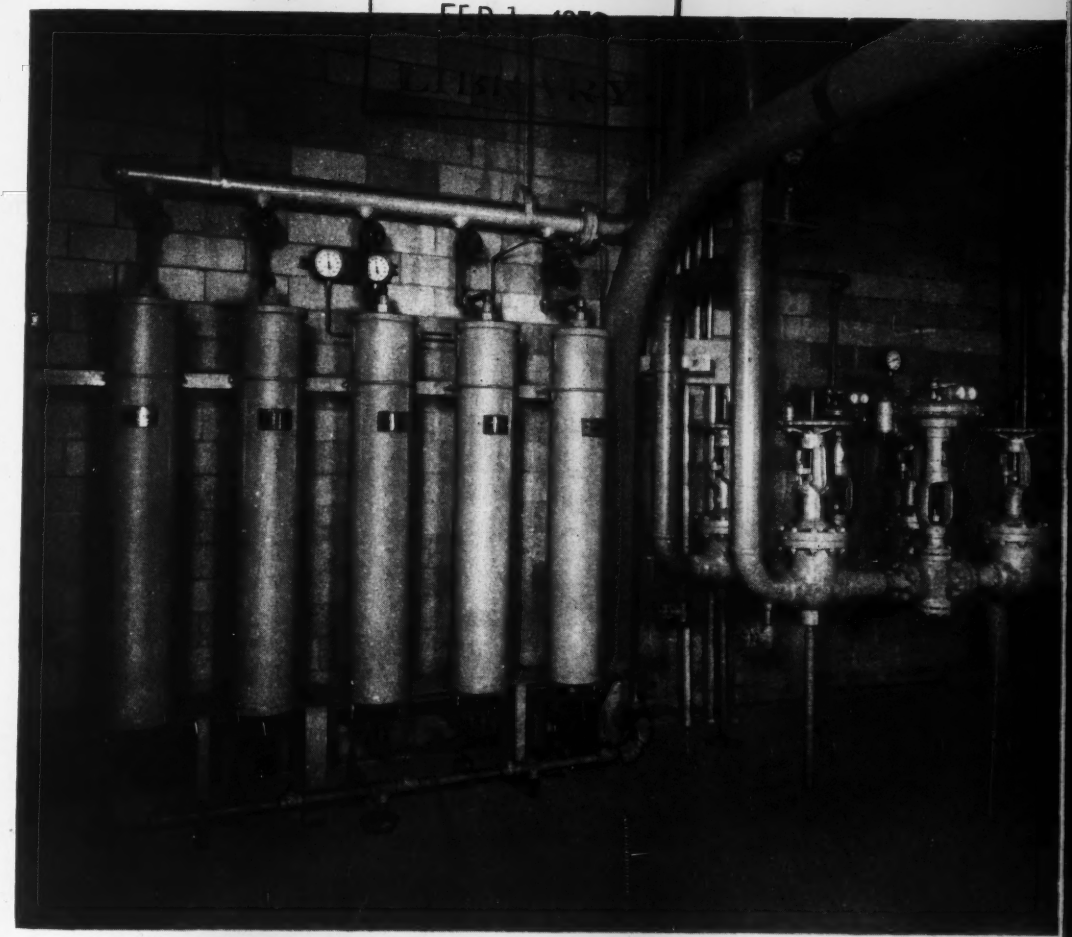
and the

JOURNAL OF THE SOUTHERN CALIFORNIA METER ASSOCIATION

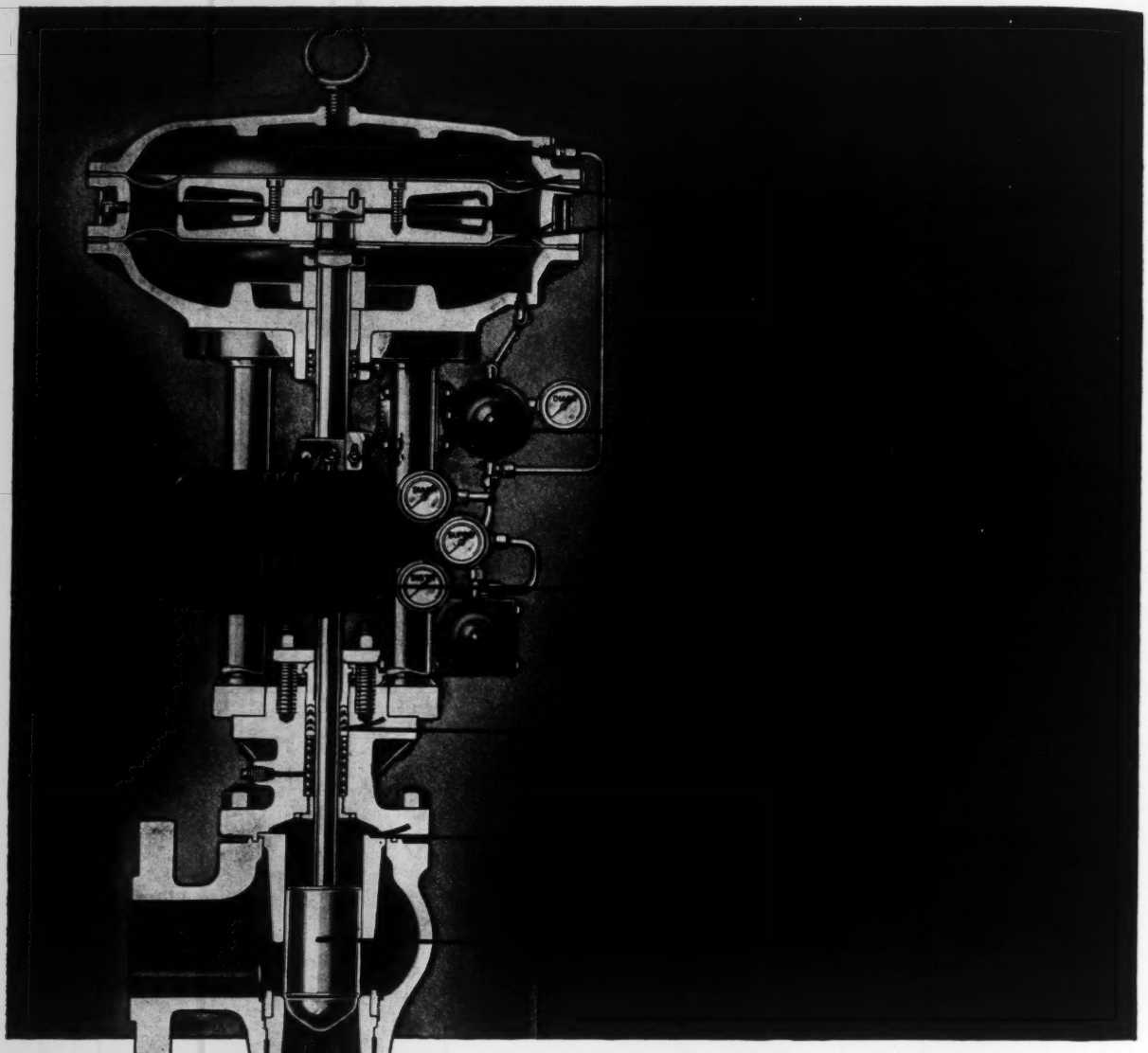
In this issue . . .

Apparatus Design
Rubber-plant Instrumentation
Optimalizing Control
Instrument Electronics
The Plasmatron
Reset Rate Adjustment
Tire-curing Instrumentation
Orifice Fundamentals
73 New Instruments
83 New Bulletins

Vol. 25 No. 2
FEBRUARY · 1952



Condensifilters protect Fisher valves and other pneumatic instruments at Mitchell Sta., West Penn Power Co., Monongahela, Penna. *(Courtesy Hankison Corp.)* Story on page 122.



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TO OPEN or CLOSE SINGLE SEATED VALVES UNDER HIGH PRESSURE DROP CONDITIONS

Fisher Type 5700-458 "AMT" pressure balanced diaphragm motor valve will actuate large single-seated valves for tight shut-off on high pressure drops. It features full pneumatic performance — no springs, no levers or weights. Double diaphragm avoids backlash effects probable with single diaphragm construction. Develops up to 5,000 lbs. stem thrust with 30 lbs. air supply. Designed for fast stroke action. Fully strokes inner valves in 13 seconds.

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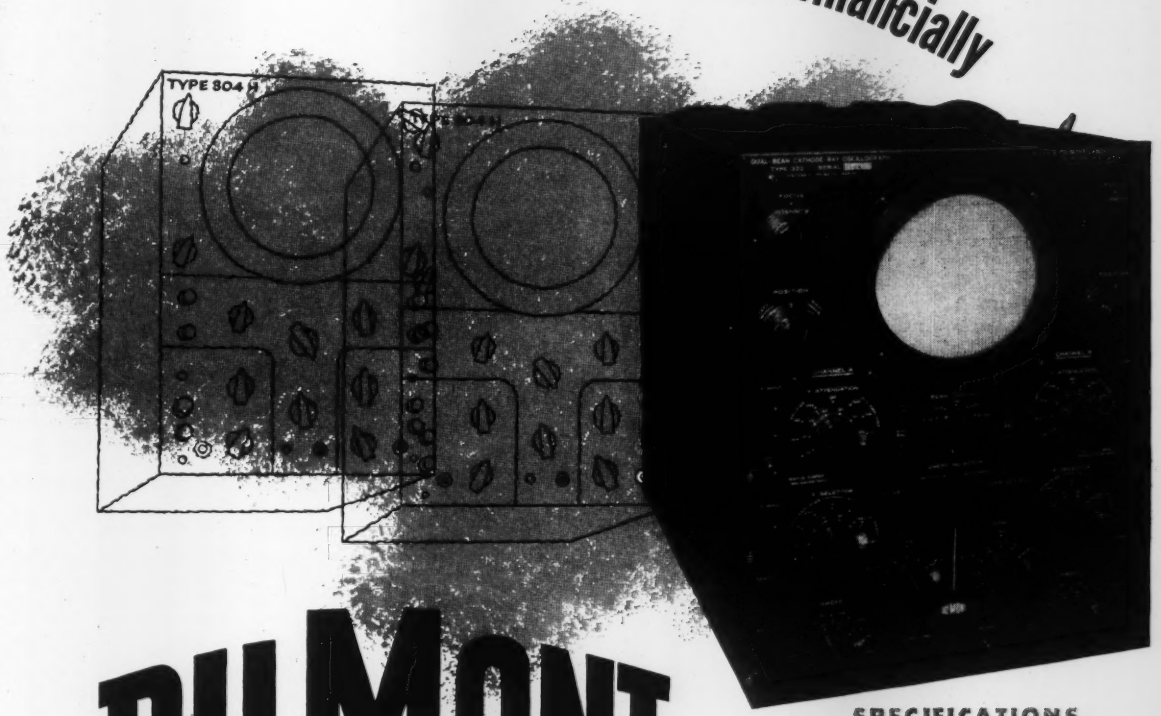
DIAPHRAGM MOTOR VALVES FOR HEAVY DUTY SERVICE

* **AMT** "Answer Me Twice". In action, pressure added to one diaphragm, subtracted from other.

FISHER GOVERNOR COMPANY Marshalltown, Iowa

A general-purpose DUAL-beam oscillograph to fit your needs technically and financially



the DU MONT TYPE 322

Not just another specialized dual-beam oscillograph, but a brand-new type designed for general development work but rugged enough for production testing and industrial applications as well. Compactness, lightweight, ruggedness and versatility mark the Du Mont Type 322 as another milestone in cathode-ray oscillography.

FEATURES **All the well-known features of the 304-H, and...**

Thoroughly field-tested.

Individual and common time bases with driven or recurrent sweeps and sweep expansion on all sweeps.

Conventional single-ended input with stepped and vernier attenuators, or balanced input with no attenuation, on both Y-axes.

Concentric controls for easy-to-operate, compact control panel.

High-gain D-C amplifiers on both channels.

Amplitude calibration on either channel on both axes.

Illuminated scale with dimmer control.

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Cathode-ray Tube — Type 5SP — Dual-beam Cathode-ray Tube. Accelerating potential, 3000 volts.

Y-Deflection Sensitivity — 0.028 peak-to-peak (0.01 rms) volts/inch from D-C to 300 KC (50% down at 300 KC); A-C coupling, 10% down at 5 c.p.s.

X-Deflection Sensitivity — 0.3 peak-to-peak (0.1 rms) volts/inch from D-C to 300 KC (down 50% at 300 KC); A-C coupling down 10% at 5 c.p.s.; common, D-C to 200 KC (down 50% at 200 KC).

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Allen B. Du Mont Laboratories, Inc.
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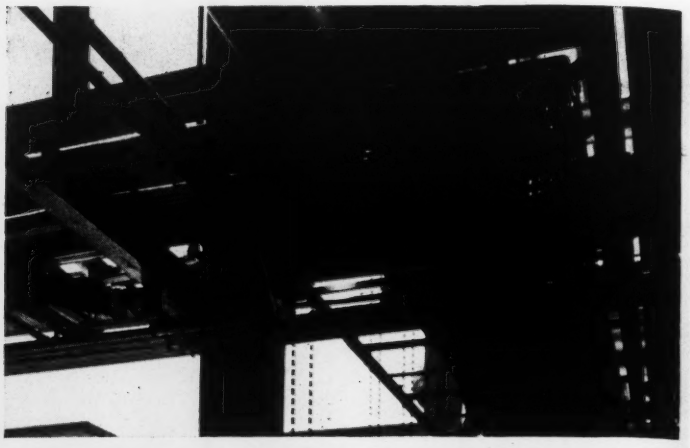
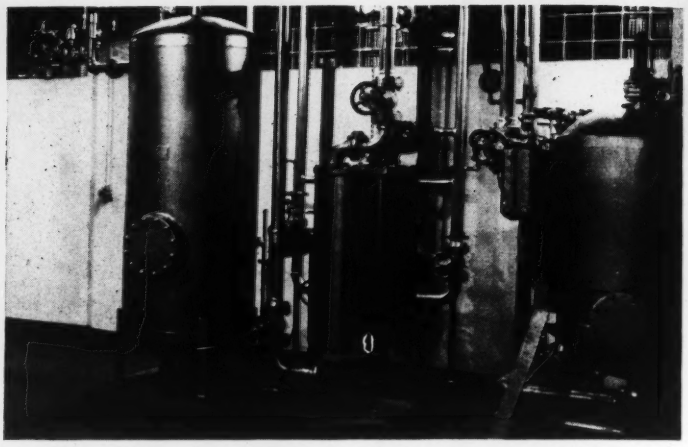


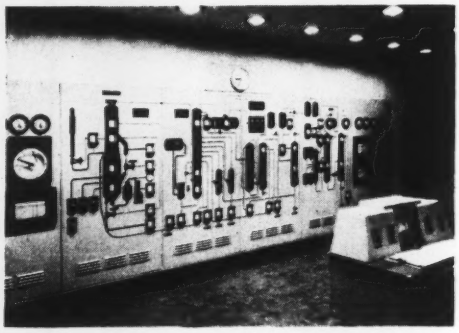


Aluminum Tubing... kept DRY by Lectrodryer

(*Upper Photo*) Instrument air lines of aluminum tubing at McMurrey Refinery Company's new, ultra-modern plant at Tyler, Texas. (*Lower Photo*) No freeze-ups, no instrument clogging because this Lectrodryer keeps air lines DRY.

Aluminum tubing resists corrosion in sulphur-laden refinery atmospheres. Team up that tubing with a Lectrodryer* to feed air to instruments at –50° F. dew point, and get maximum instrument accuracy. No moisture to cause freeze-ups. No rust, scale or sludge to clog delicate instrument ports.

Lectrodryers do away with WETth (unwanted moisture) in air, gases and organic liquids. They can give you DRYness down to three or four parts per million—continuously, automatically, economically. Let us work with you when you have to stop WETth. We've been helping organizations like yours for 20 years. Pittsburgh Lectrodryer Corporation, 303 32nd Street, Pittsburgh 30, Penna.



McMurrey's control room is a model of clean, functional design.

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LECTRODRYER

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Pressures to 10,000 psi.
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- NO LUBRICATION
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- NO SHAFT FREEZING

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Instruments

THE MAGAZINE OF MEASUREMENT INSPECTION • TESTING • CONTROL

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Continued on page 122

LEWIS TEMPERATURE INDICATORS FOR AIRCRAFT

TO AIR FORCE SPECIFICATIONS

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2" Single shown with removable Bezel. For exhaust temperature, range 0 to 1000°C, Chromel-Alumel.

2¾" Dual shown with removable Bezel. For exhaust temperature range 0 to 1000°C, Chromel-Alumel.

2" Single, for ring clamp mounting. For cylinder temperature, range −50 to +300°C, Iron-Constantan.

RESISTANCE TYPE

12 or 24 volt ratiometers

2" Single, range −70 to +150°C oil temperature indicator, for ring clamp mounting.

2" Single, range −50 to 50°C for carburetor-air temperature indication, ring-clamp mounted.

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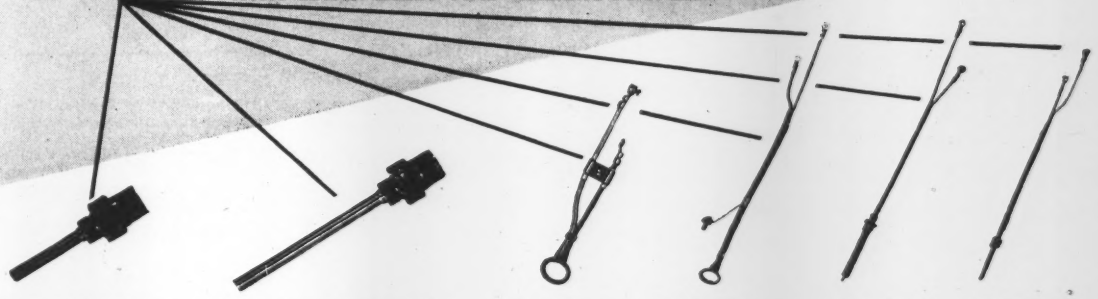
Available in all standard ranges for cylinder head, bearing carburetor-air, coolant, oil, free-air and heating-duct temperatures. For best results, use LEWIS resistance bulbs as sensing elements with LEWIS instruments. Any of above instruments may be supplied with type A-1 bezel if specified.

AIRCRAFT RESISTANCE BULBS AND THERMOCOUPLES

FOR BEST RESULTS USE LEWIS INSTRUMENTS WITH LEWIS BULBS AND THERMOCOUPLES



STANDARD AN5525-1 with 1⅞ in. stem

STANDARD AN5525-2 with 4 in. stem

AN5540-1

AN5540-2

AN5545-1

AN5541-1

In addition to the standard "AN" Types illustrated, we manufacture thermocouples for test work as well as special types to customer's specifications.

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Manufacturers of *Complete* Temperature Measuring Systems for Aircraft

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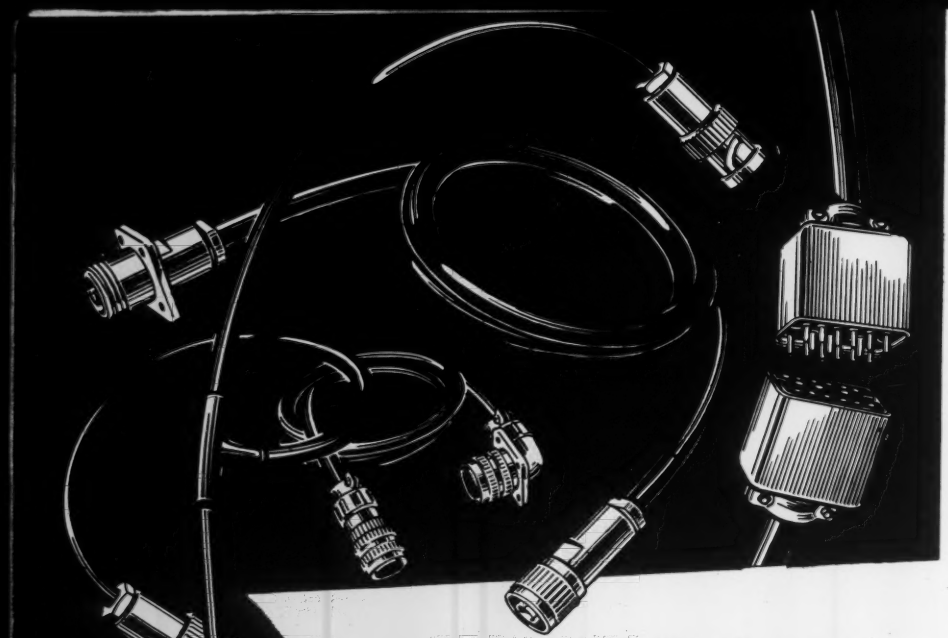

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CABLE HARNESSES produced by Amphenol are assembled with the same care and rigid inspection that characterizes *all* components manufactured by Amphenol. Electrical inspection includes insulation resistance, continuity and high voltage breakdown tests. All assemblies meet and are superior to the rigid Army-Navy specifications. Specifying Amphenol complete cable assemblies cuts costs, saves valuable man hours and insures against losses due to errors and rejects.

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COVER STORY

The photograph on the front cover shows a 5-unit battery of Hankison Condensifilters installed in the Mitchell Station of West Penn Power Company at Monongahela, Penna. The Condensifilters remove water and oil by condensing vapor, and dirt and sludge by absorption on flannel filter cartridge. The entire plant air supply for hundreds of pneumatic devices, including valves and controllers, is cleaned and dehydrated in this battery of filters. The Condensifilters eliminate the need for special instrument-air compressors.

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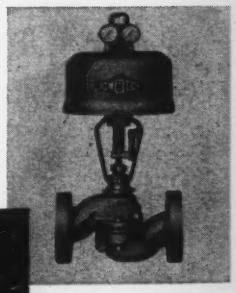

The Annin Domotor valves provide positive control of corrosive, erosive fluids and fluids containing semi-solids.

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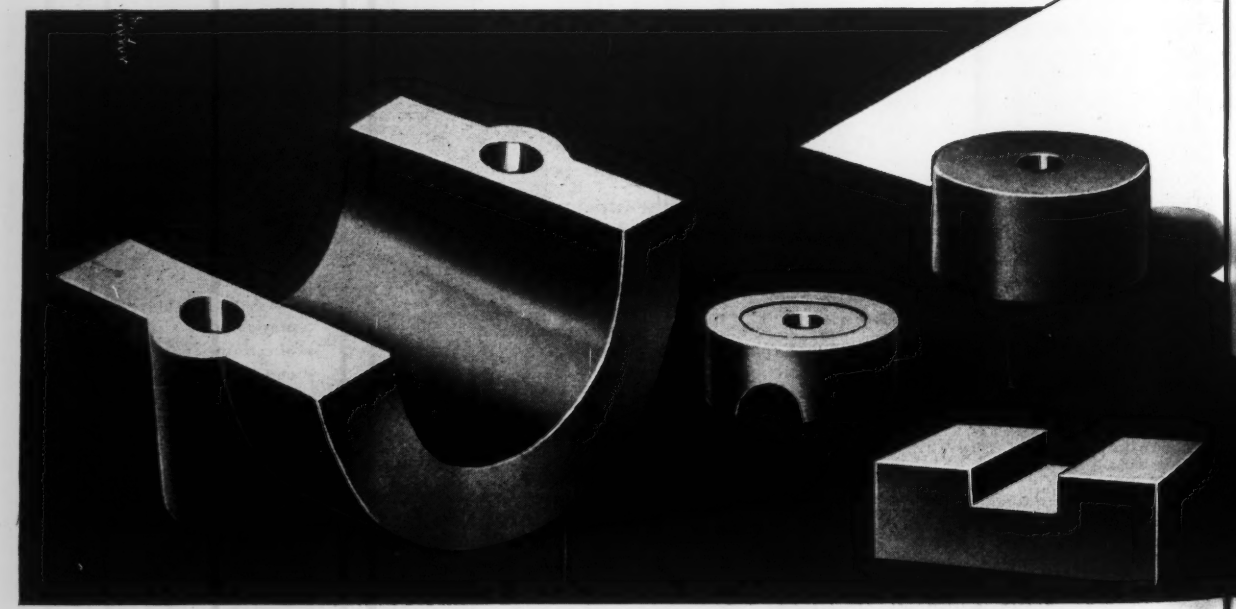

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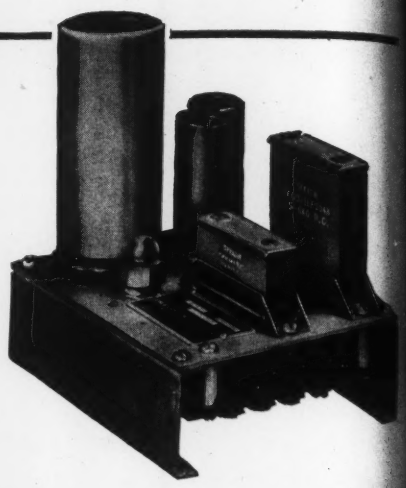

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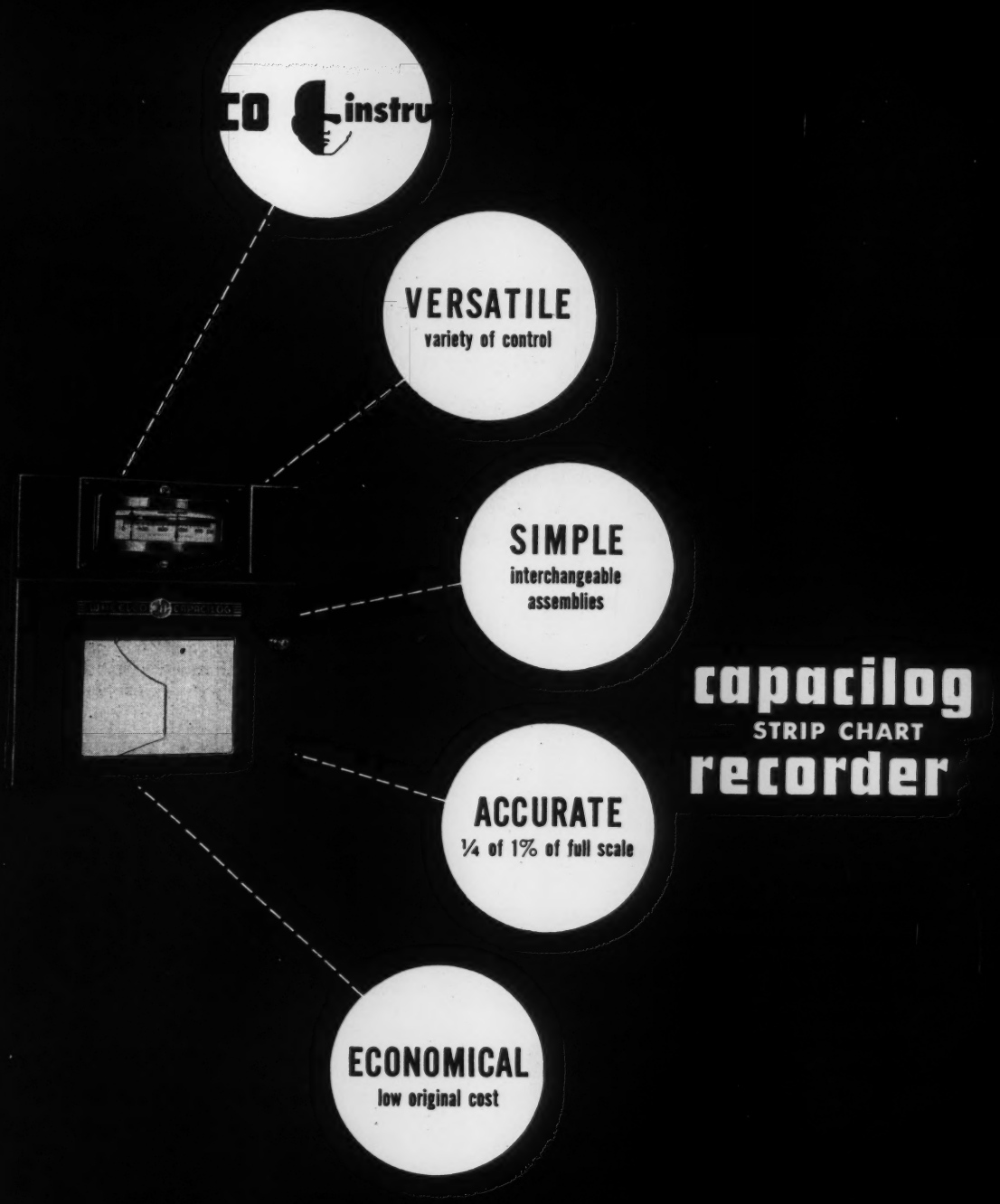

wheelco electronic controls

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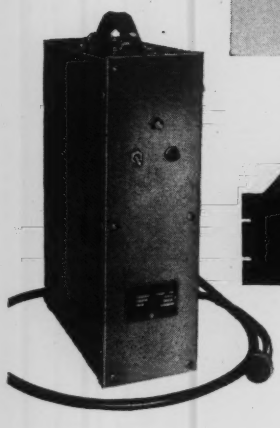
Two types of STABILINE Automatic Voltage Regulators are offered by The Superior Electric Company to meet the requirements of maintaining constant a-c voltage to electrical equipment.

IE



IE51002

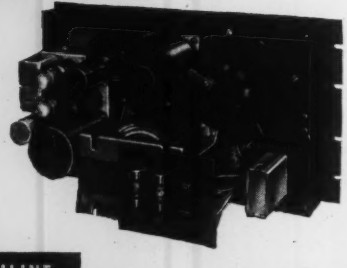
IE51002R

INSTANTANEOUS ELECTRONIC

Type IE is a completely electronic unit with no moving parts. It provides almost instantaneous correction of line voltage or load changes. Waveform distortion never exceeds 3 per cent. Output voltage is held to within ± 0.1 per cent of nominal for wide line variations; to within ± 0.15 per cent of nominal for any load current change or load power factor change from 0.5 lagging to 0.9 leading. Type IE is versatile in application finding wide use in laboratory work, on test lines and as a component of other equipment where the most exacting voltage regulation is necessary. There are 28 standard models for 115 and 230 volts, 50 or 60 cycles, single phase operation ranging in capacity from ¼ to 5 KVA. Special units are available for higher frequency operation . . . to meet government agency specifications . . . or for unusual applications.

EM

EM4102



EM4102R

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Type EM is an electro mechanical unit with a very sensitive detector controlling a motor-driven POWERSTAT variable transformer which feeds a buck-boost auxiliary transformer. Its outstanding advantages are zero waveform distortion and high efficiency. Type EM is most often used in the control of industrial loads. However; the demand of today's electronic equipment for constant voltage with absolutely zero waveform distortion necessitates the incorporation of a type EM as an integral part of the assembly. Type EM is offered in standard models for 115, 230 and 460 volts, 50 and 60 cycles, single and three phase duty in ratings from 2 to 100 KVA. Special units can be designed for higher frequencies, for conformance to government agency requirements and for individual needs.

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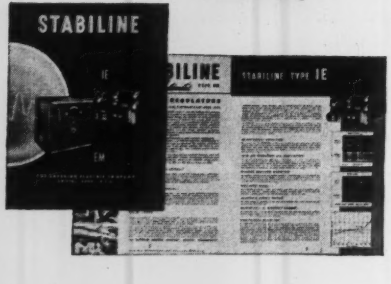

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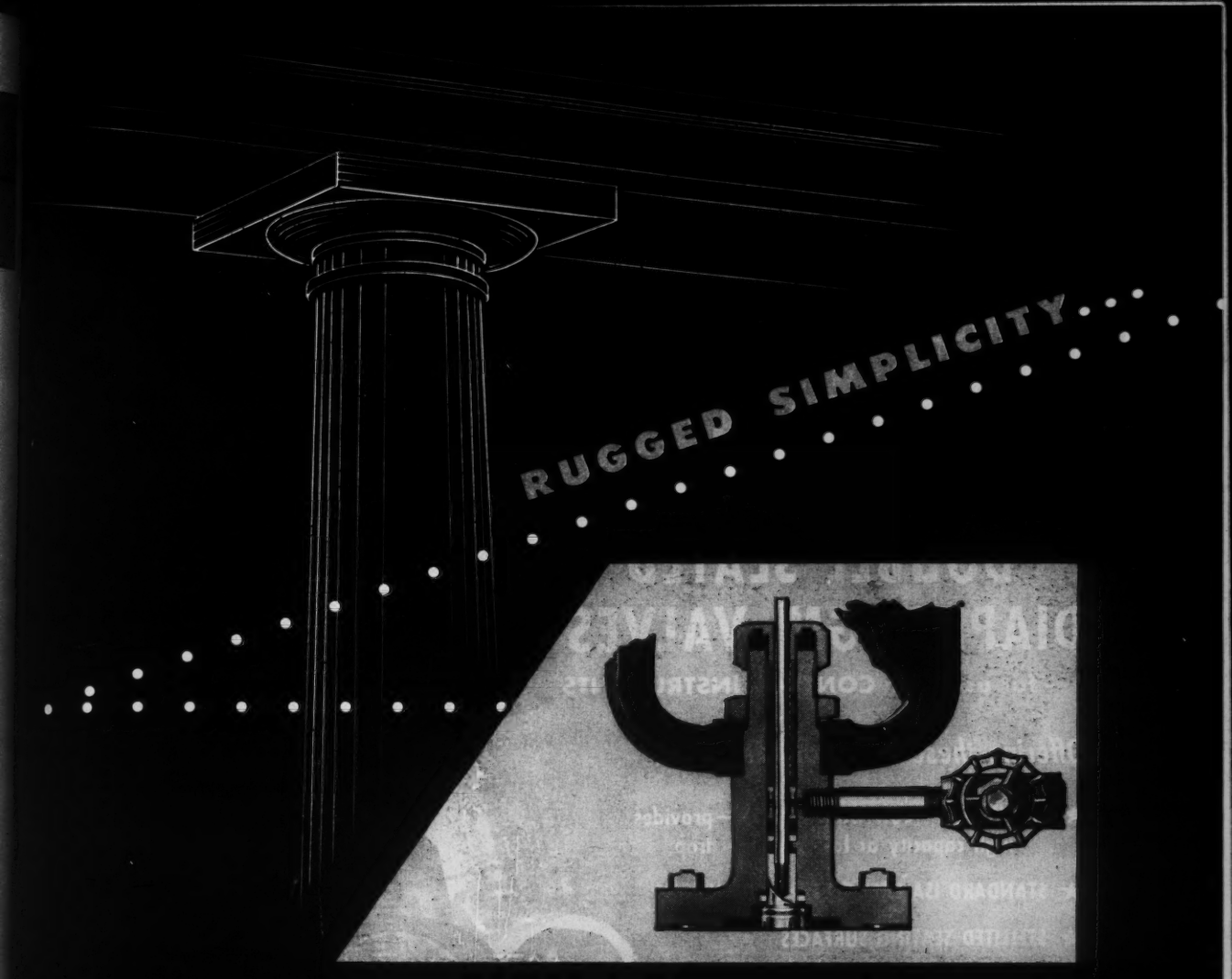
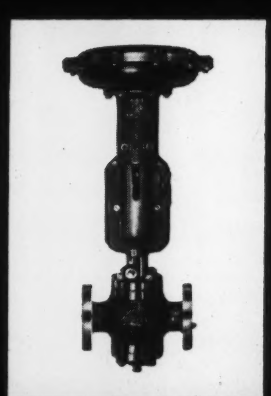


through one-piece bonnet construction



The rugged, jointless, steel bonnet of the Honeywell Series 700 Valve affords greater strength, simpler disassembly for inspection and maintenance . . . has deep, integral stuffing box built to superior performance standards, top-and-bottom packed lantern gland to minimize leakage. The Honeywell Series 700 wide band proportioning valve comes in a full range of styles and sizes . . . has *all* the features you look for in a fine valve. Write today for your copy of Bulletin 700-3.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division,* 1908 Windrim Ave., Philadelphia 44, Pa.

MINNEAPOLIS
Honeywell
VALVE PRODUCTS

H
HONEYWELL

First in Controls

Announcing

the New TRADE LESLIE MARK

DOUBLE SEATED DIAPHRAGM VALVES

— for use with CONTROL INSTRUMENTS

Offering these Important Features:

★ "FLOW-LINE" CONTOURED BODY—provides high capacity at low pressure drop.

★ STANDARD ISA FACE-TO-FACE DIMENSIONS

★ STELLITED SEATING SURFACES

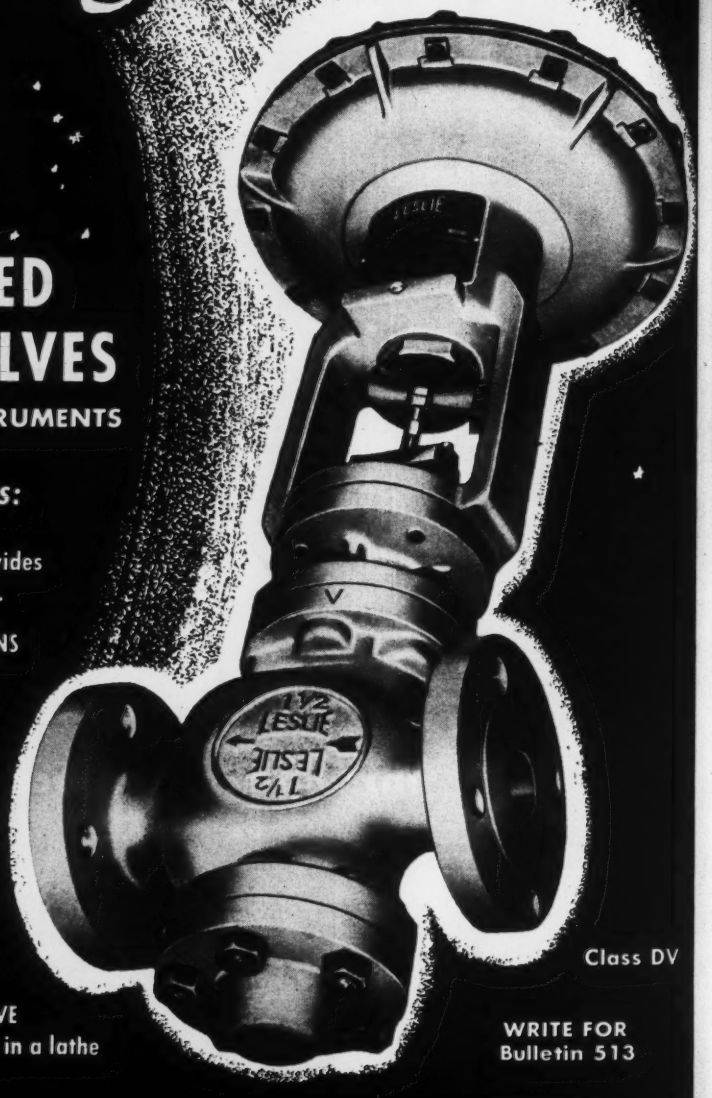
★ RENEWABLE SELF-ALIGNING GUIDES

★ POWERFUL, COMPACT FRICTION-FREE DIAPHRAGM SUPERSTRUCTURE

★ THROUGH-BOLT CONSTRUCTION ON STEEL VALVES

★ WIDE RANGEABILITY

★ SEAT RINGS EASILY REPLACED WITH VALVE IN PIPELINE—not necessary to set up in a lathe or grind in at high temperature.



Class DV

WRITE FOR Bulletin 513

Available with various size superstructures. Sizes 1½" to 10" in Cast Steel and Cast Iron.

Look for LESLIE REGULATORS under "Valves" or "Regulators" in your classified telephone directory in the following cities where LESLIE factory trained engineers are located:

Albany, N. Y.	Cincinnati, Ohio	Kansas City, Mo.	New Orleans, La.	Rutherford, N. J.
Albuquerque, N. M.	Cleveland, Ohio	Kingsport, Tenn.	New York, N. Y.	Salt Lake City, Utah
Atlanta, Ga.	Dallas, Texas	Los Angeles, Cal.	Orlando, Fla.	San Francisco, Cal.
Baltimore, Md.	Denver, Colo.	Louisville, Ky.	Philadelphia, Pa.	Seattle, Wash.
Beaumont, Texas	Des Moines, Ia.	Memphis, Tenn.	Pittsburgh, Pa.	St. Louis, Mo.
Birmingham, Ala.	Detroit, Mich.	Minneapolis, Minn.	Ponca City, Okla.	Syracuse, N. Y.
Boston, Mass.	Duluth, Minn.	Mobile, Ala.	Portland, Ore.	Tarrytown, N. Y.
Bridgeport, Conn.	Greensboro, N. C.	Newark, N. J.	Providence, R. I.	Tucson, Ariz.
Buffalo, N. Y.	Greenville, S. C.	New Haven, Conn.	Richmond, Va.	Wilmington, Calif.
Chicago, Ill.	Houston, Texas	Norfolk, Va.	Rochester, N. Y.	Youngstown, Ohio

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1503

ESTABLISHED 1900

LESLIE CO.

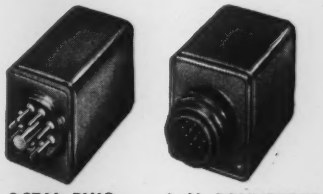
299 Grant Avenue, Lyndhurst, New Jersey

FLOATLESS LEVEL CONTROLS • PUMP GOVERNORS • TEMPERATURE REGULATORS
SELF CLEANING STRAINERS • AIR HORNS • STEAM WHISTLES

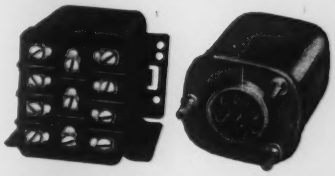
PRESSURE REDUCING VALVES • PRESSURE CONTROLLERS

FOR TANKS OR BANKS

Fast . . . accurate . . . the power, gun firing, turret control and communications in a fighting tank depend on expert industrial design and production techniques on the homefront, where speed and precision meet again in business machine "paper work". In mills, factories and in banks Guardian Relays control devices that count—compute—sort—convey—package—vend—meter and mail. Basic . . . flexible . . . government approved . . . *hermetically sealed* or open type mounted . . . Guardian Relays serve all fronts . . . will serve you well!



OCTAL PLUG A. N. CONNECTOR



SCREW TERMINAL LUG HEADER

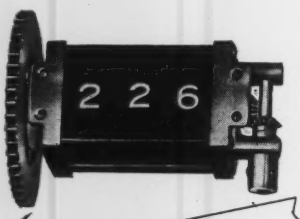
AN-3320-1 D.C. AN-3324-1 D.C. Series 595 D.C. Series 610 A.C.—615 D.C. Series 695 D.C.

Get Guardian's New HERMETICALLY SEALED RELAY CATALOG Now!

GUARDIAN ELECTRIC

1638-B W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY



Small Component... or Complete Unit... You* can count on getting whatever You* need—

Added Evidence that—

Everyone Can Count on VEEDER-ROOT

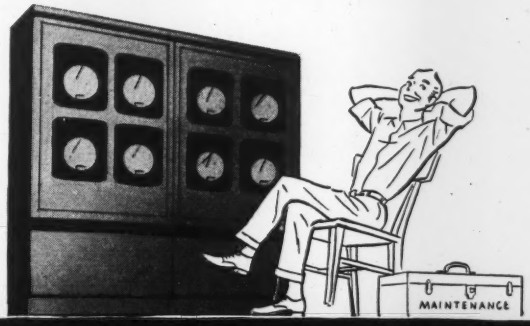
This REEL CONTROL BOX, complete with its *built-in* counting mechanism, indicates the number of feet of antenna reeled in and out of certain types of military aircraft. Manufactured completely by Veeder-Root, including outside bakelite cover and box, this unit shows another imaginative application of the universal language of direct-reading *Count*rol.

Now if you, *in any of your defense work,** have a counting problem, then you can count on Veeder-Root to help you in every possible way.

VEEDER-ROOT INCORPORATED
"The Name That Counts"
HARTFORD 2, CONN. • GREENVILLE, S.C.
Montreal 2, Canada • Dundee, Scotland
Offices and agents in principal cities

"Counts Everything on Earth"

WHY maintenance men breathe easier...



DYNALOGS* have

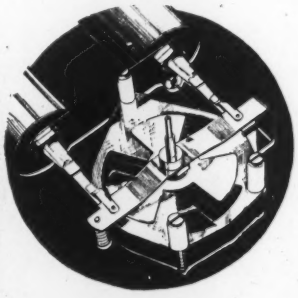
PRACTICALLY NO MAINTENANCE

With Dynalog Recorders and Controllers, maintenance men are freed from hazards of sticking electrical contacts and worn slidewires . . . freed from routine lubrication and cleaning of balancing motors, periodic standardizing and replacement of batteries. No wonder maintenance men breathe easier!

The simplicity of Dynalog design is one reason for its unequalled freedom from maintenance. In the entire balancing mechanism there are only four moving parts (none moving faster than the pen). It's free from the gears, cables, etc. used in conventional bridge-type instruments . . . the result of advanced engineering from concept to construction.

Freedom from maintenance is only one of many important advantages of Dynalog Instruments. They offer . . . *speed* that's full scale to new balance in as little as one second . . . *sensitivity*, one ten-thousandth of scale . . . *accuracy*, ¼ of 1% of scale. Available for measurement and control of temperature (with resistance bulbs or thermocouples), humidity, pressure, flow, force, pH, conductivity, etc. Get the complete story in Bulletin 427-1. Write **The Foxboro Company, 46½ Neponset Ave., Foxboro, Mass., U.S.A.**

*Reg. U. S. Pat. Off.



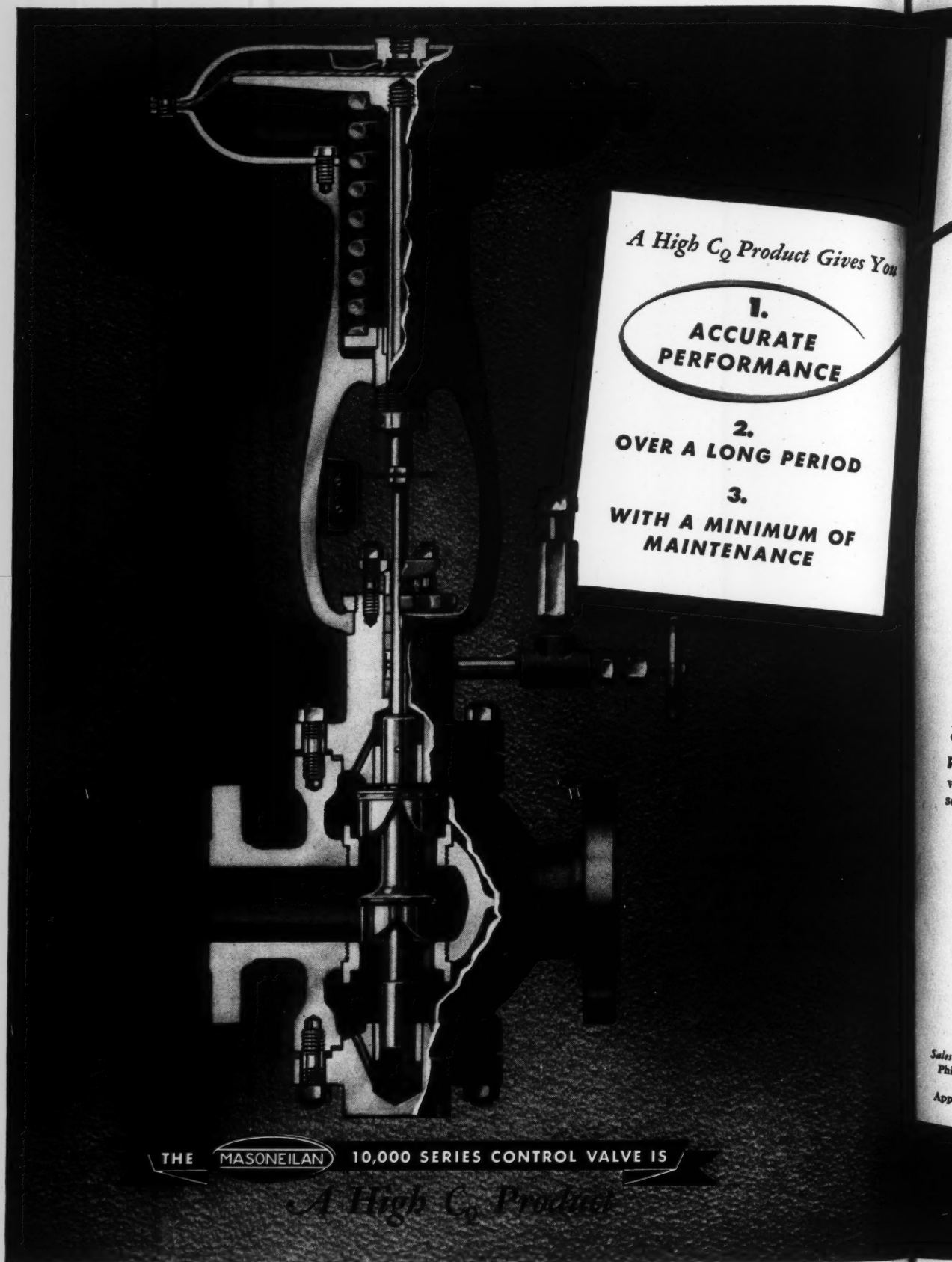
The heart of Dynalog superiority

It's a simple variable capacitor! Taking the place of the conventional slidewire, this important component gives Dynalog Instruments absolutely STEPLESS continuous balancing. It gives you an instrument of extreme accuracy and stability, with a sturdiness that withstands the most severe industrial conditions.

FOXBORO DYNALOG*

Reg. U. S. Pat. Off.

The electronic potentiometer that has NO SLIDEWIRE


A High C_Q Product Gives You
1.
ACCURATE PERFORMANCE
2.
OVER A LONG PERIOD
3.
WITH A MINIMUM OF MAINTENANCE
THE MASONEILAN 10,000 SERIES CONTROL VALVE IS
A High C_Q Product

In Control Valve Performance the No. 1 Quality Factor is

Accuracy

A number of other quality factors enter into the design and manufacture of a control valve which provides "accurate performance, over a long period, with a minimum of maintenance". Such interrelated factors as rugged mechanical construction; selection of materials, types, sizes, and associated equipment; convenience in servicing, etc. are important. But without accurate performance these are meaningless.

Here is how Masoneilan Control Valves are designed and built to assure this accurate performance:

Correct Flow Characteristics
Plug contours designed and flow tested to provide accurate flow characteristics over widest practical range. A variety of precision machined plugs permits selection of most suitable construction as well as the desired flow characteristics for the service conditions.

Wide Flow Range
Low minimum flow (because of smallest practical clearance between plug and seat ring obtainable by precision machining), large diameter seat rings and long stroke combine to insure wide usable flow range.

Large Body Flow Areas
provide required C_v with minimum pressure drop due to body restrictions.

Responsive, Positive Diaphragm Motor
with large diaphragms, pre-formed to provide sensitivity and power, to maintain effective area throughout valve stroke and to minimize hysteresis. Calibrated springs for 3-15 or 6-30 psi range. Stop in upper diaphragm case establishes correct initial diaphragm position, avoiding faulty adjustment.

Accurate Alignment
from diaphragm to blindhead, insured by pre-formed diaphragm; by precision control of clearance in stuffing box parts, guide bushings and plug guide section; by piloting of seat rings in body bridge wall; by piloting one-piece bonnet and blindhead in body; by rigid fastening of diaphragm motor to body by heavy forged steel drive nut.

Minimum Friction
insured by accurate alignment; by finish of honed and highly polished valve stems; by finish of extra deep stuffing box parts; by self-aligning frictionless guide provided by diaphragm; by oilite bronze lower guide.

In selecting control valves consider first the "Accuracy of Performance" quality factor — but evaluate the other quality factors too — the factors that insure accuracy "for a long period, with a minimum of maintenance". For the sum of *all* quality factors is the C_Q (Quality Coefficient) and in comparing cost remember that the *real* cost includes invoice price plus cost of maintenance and down-time. Thus for comparison, among comparably priced valves the best buy is the one with the highest Quality Coefficient —

$$\text{for Real Cost} = \frac{\text{Price}}{C_Q}$$

MASON-NEILAN REGULATOR CO.

1210-A ADAMS STREET, BOSTON 24, MASS., U.S.A.

Sales Offices or Distributors in the Following Cities: New York • Syracuse • Chicago • St. Louis • Tulsa Philadelphia • Houston • Pittsburgh • Atlanta • Cleveland • Cincinnati • Detroit • San Francisco Salt Lake City • El Paso • Boise • Albuquerque • Charlotte • Los Angeles • Denver Appleton • Corpus Christi • New Orleans

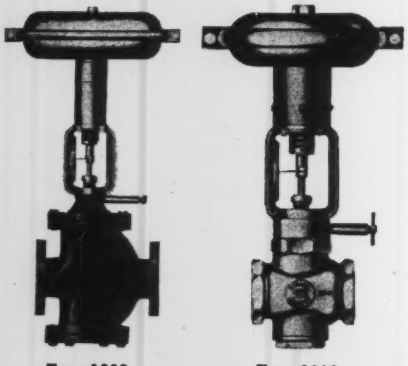
Mason-Neilan Regulator Co., Ltd., Montreal and Toronto

Why Most Leading Companies Are Using K & M Control Valves

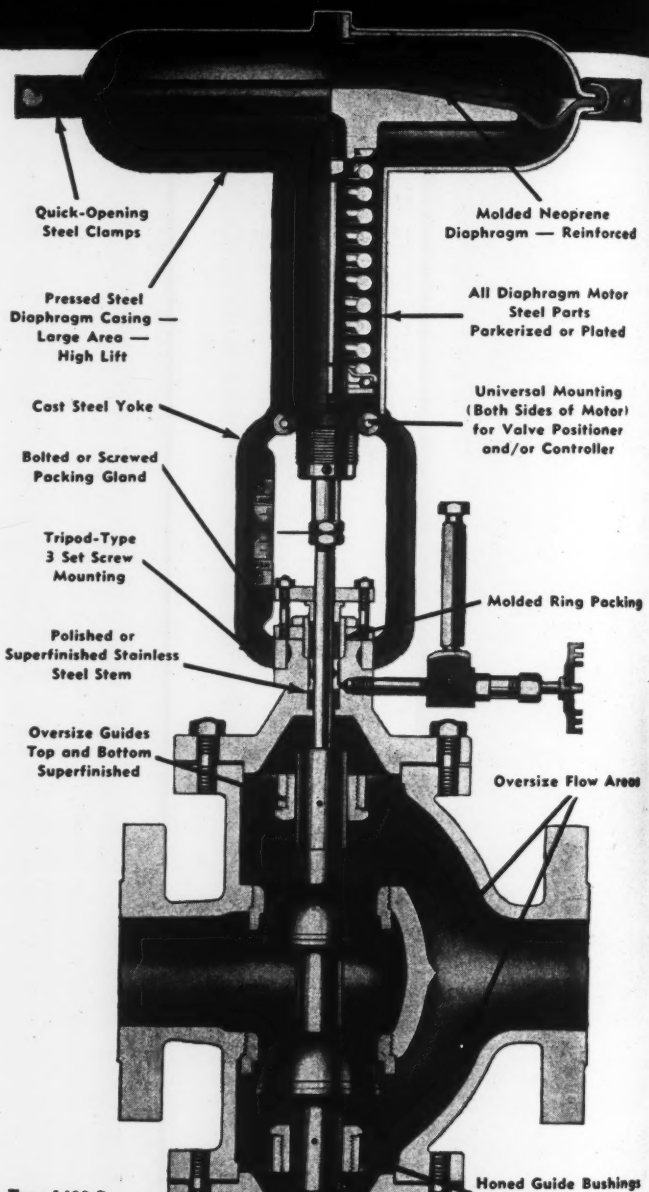
It is logical that leading companies should handle the important subject of control valves as they do other matters: They make use of the best available skills and thinking. More and more, they utilize the equipment, knowledge and facilities of the K & M engineering and service team.

Five years ago, K & M Advanced-Type Control Valves were new to industry. Today, with outstanding performance records behind them, K & M valves have become first in the regard of many instrument engineers. Increasingly, K & M representatives are called upon to give counsel and assistance in the planning of new control installations and the improvement of old ones. During the past year K & M men have been consulted on most of the projects in which control valves have been a major consideration.

There is a qualified K & M representative near you, eager to discuss your problems and able to help you with them.



Type 1200 Type 1000


Quick-Opening Steel Clamps
Pressed Steel Diaphragm Casing — Large Area — High Lift
Cast Steel Yoke
Bolted or Screwed Packing Gland
Tripod-Type 3 Set Screw Mounting
Polished or Superfinished Stainless Steel Stem
Oversize Guides Top and Bottom Superfinished
Molded Neoprene Diaphragm — Reinforced
All Diaphragm Motor Steel Parts Parkerized or Plated
Universal Mounting (Both Sides of Motor) for Valve Positioner and/or Controller
Molded Ring Packing
Oversize Flow Areas
Honed Guide Bushings Top and Bottom

Type 1400 R

K&M

KIELEY & MUELLER, INC.

Valve Makers Since 1879

2017—43rd STREET NORTH BERGEN, N. J.

G-E Pyrometer Equipment Quick and Easy to Inspect, Maintain

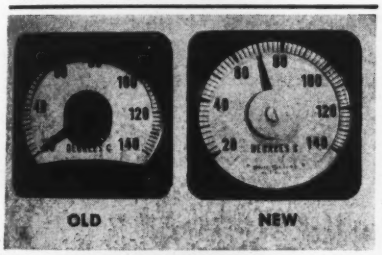
Routine inspections of new General Electric Type HP pyrometers can quickly be made. Besides making preventative maintenance easy, this equipment has many other features to provide accurate indication and temperature control of furnaces, ovens kilns, and other industrial heating equipment.

ACCURATE WITHIN ¾ OF 1% full scale, HP-3 pyrometers have automatic cold-junction compensation that adjusts for changes in ambient temperature.

Any change in temperature, even as small as 0.1% full scale, starts immediate control action. Normal changes in humidity, ambient, and voltage have little or no effect on the exactness of control action.

FOUR TYPES AVAILABLE—indicating, protecting, two- and three-position control forms; also both flush and surface mountings. All available in a variety of temperature ranges in the 0-3000 F span.

Mail the coupon for complete information about Type HP pyrometers.



New Shadow-proof Temperature Indicators Are Easier to Read

Temperatures from −100 F to +300 F can now be accurately indicated and controlled with General Electric's new line of temperature indicators. These instruments can be read from almost any angle. The dial is set forward, flush with the front of the case. A protruding convex-type glass front provides clear illumination. No more cover overhang; no more shadows caused by overhead lighting. Two sizes available—4¼- and 8¾-inches. Check coupon.

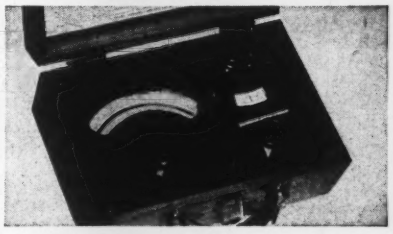
New Resistance Thermometers Accurately Indicate and Control Low Temperatures

TEMPERATURES FROM −100F to +300 F can now be accurately indicated and controlled with General Electric's new line of resistance thermometers. They indicate accurately within ¾ of 1 per cent full scale. Any change in temperature equivalent to 1/10 of 1 per cent full scale starts immediate control action.

Normal changes in humidity or room temperature do not affect the exactness of control. Neither does a change in control voltage. Sturdy, simple construction assures reliable operation under severe operating conditions.

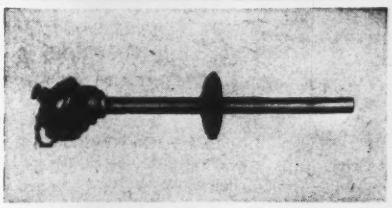
NARROW TEMPERATURE SPANS, as small as 90 degrees, are available anywhere in the −100 F to +300 F range. You can buy four types of resistance thermometers—indicators, protectors, and two- or three-position controllers—for either flush or surface mounting.

For complete information, mail the coupon below.



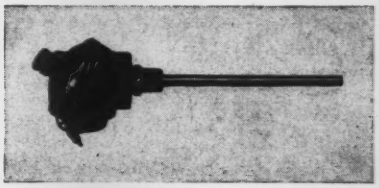
THERMOCOUPLE POTENTIOMETER measures temperature in locations inaccessible to glass-stem thermometers. Any number of different readings can be taken in rapid succession and accurate within ±0.2% of full scale.

Typical applications include refrigerator-development work, oil-burner and air-conditioning tests, steam temperature measurements, and heat-run tests on electric equipment. For complete information, mail the coupon below.



THERMOCOUPLES, COMPONENTS, AND ACCESSORIES for your pyrometer installations include protecting tubes and wells, thermocouple wire, ceramic insulators, extension wire, connectors, heads, selector switches. Send coupon today for catalog to help you obtain proper thermocouple assemblies.

Resistance Bulbs Accurate Within ±1 F between −100 F and +300 F



FOR ANY RESISTANCE THERMOMETER INSTALLATION, new G-E resistance bulbs offer a high degree of accuracy and reliability. They're available either with completely enclosed terminal head or without terminal head and with four feet of flexible cable. Units will retain calibration within 0.1 F. For complete information, mail the coupon below.

SECTION S 602-227, GENERAL ELECTRIC SCHENECTADY 5, N. Y.

Please send me the following bulletins: Indicate:

- \ for reference only
- x for planning an immediate project
- ☐ Resistance Thermometer (GEC-835)
- ☐ Resistance Bulb (GEC-835)
- ☐ Type HP-3 Pyrometer (GEC-713)
- ☐ Temperature Indicators (GEC-218B)
- ☐ Thermocouples, Accessories (GEC-714)
- ☐ Thermocouple Potentiometer (GEC-245)

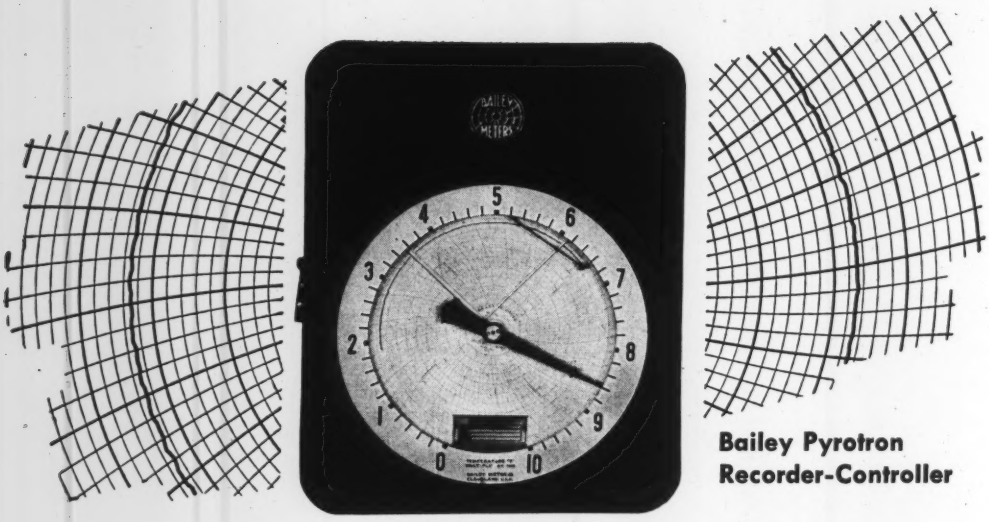
NAME.....

COMPANY.....

STREET.....

CITY..... ZONE.... STATE.....

GENERAL ELECTRIC



Bailey Pyrotron
Recorder-Controller

Looking for Better Temperature Instruments?

...Then check these features of Pyrotron Electronic Resistance Thermometers...

FUNDAMENTAL ACCURACY

Bailey Pyrotron Resistance Elements are made of highest purity platinum—the material used by the National Bureau of Standards in establishing basic standards for temperatures from −190°C to +660°C.

THREE TYPES OF CONTROL

Pyrotron Controllers may operate: on-off electrical systems by either electronic relays or electric contacts, modulated electronic systems, or air-operated systems. Two temperatures may be recorded on the same chart and controlled by a single instrument.

FACTS PUT INTO USABLE FORM

Bailey Pyrotrons may be arranged to put temperature facts into convenient usable forms. If two or more temperatures are related, they may be recorded as continuous records on the same chart for easy comparison. The average of several temperatures or the difference between two temperatures may be recorded as a single continuous record which may be retransmitted to a distant point or used to actuate a control system.

EASY INSTALLATION

Bailey Pyrotrons do not require careful leveling or protection against vibration. Three ordinary copper wires are all that is needed to connect each temperature sensitive element with the recorder. Power may be taken from any 115 volt 60 cycle circuit.

MINIMUM MAINTENANCE

The absence of galvanometers, batteries and standardizing equipment, together with the use of interchangeable unit assemblies, reduces Pyrotron maintenance to the vanishing point.

ABUNDANT POWER

A separate motor drive for each temperature furnishes abundant power to operate a recording pen, a controller and an alarm switch.

For the full story on this unusual electronic resistance thermometer which is suitable for ranges between −300°F and 1200°F, ask for Bulletin No. 230-C. P-21

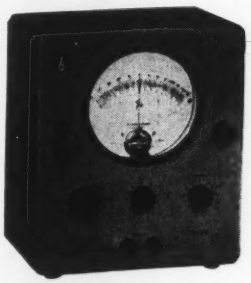
BAILEY METER COMPANY

1041 IVANHOE ROAD • • • CLEVELAND 10, OHIO

Controls for Processing

TEMPERATURE
PRESSURE
% OXYGEN
% COMBUSTION
FLOW
LEVEL
DENSITY
RATIO

Simplify electrical studies with these Brush instruments

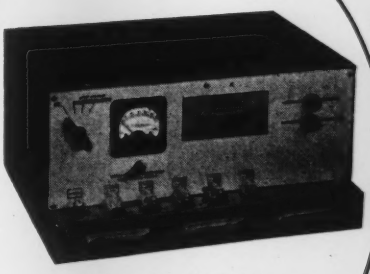


Brush Deviation Test Bridge

SPEEDS UP INSPECTION. Resistors, capacitors and inductors are rapidly and accurately inspected by this Brush Deviation Test Bridge. Indicates percentage of deviation of a test component from the standard. Has large, easy-reading dial. Very high indicating speed permits testing at rates as high as 4,000 elements per hour. Free bulletin on request.

RECORDS TWO PHENOMENA SIMULTANEOUSLY. This team of Brush Dual Channel Amplifier and Magnetic Oscillograph are here being used to record generator voltage and field current time-curves. This simplifies plotting of saturation curve to study build-up of voltage. Requires only a few minutes . . . compared to hours for conventional plotting methods. Investigate these Brush instruments for the study of many other electrical variables. Write for bulletin.

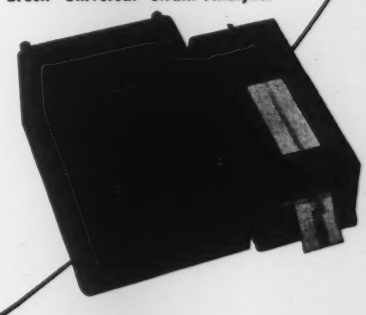
REGULATES FREQUENCY. The Brush Regulated Frequency Power Supply furnishes moderate power at 60 cycles that is completely unaffected by the frequency of the primary power source. It will govern the operation of fractional horsepower synchronous motors at fixed speed or set the characteristics of controls where accurate frequency is essential. No adjustments are needed for any loading from zero to full capacity of 60 watts. Rugged construction permits use in field. Frequency accuracy is one part in 100,000. Write for complete information and specifications.



Brush Model BL-809
Regulated Frequency Power Supply

FOR PHYSICAL VARIABLES. The Brush "Universal Analyzer" gives instantaneous, accurate recording of a wide variety of physical variables such as strain, pressure, acceleration, torque, force, temperature, displacement and vibration. This new Brush Analyzer, consisting of a Carrier Type Bridge Amplifier and Direct-Inking Oscillograph, is a complete unit. You simply connect it to your standard pickup elements. With proper calibration resistors, its ink-on-paper records can be interpreted immediately and easily in any desired units of physical measurement. Write today for complete details.

Brush "Universal" Strain Analyzer

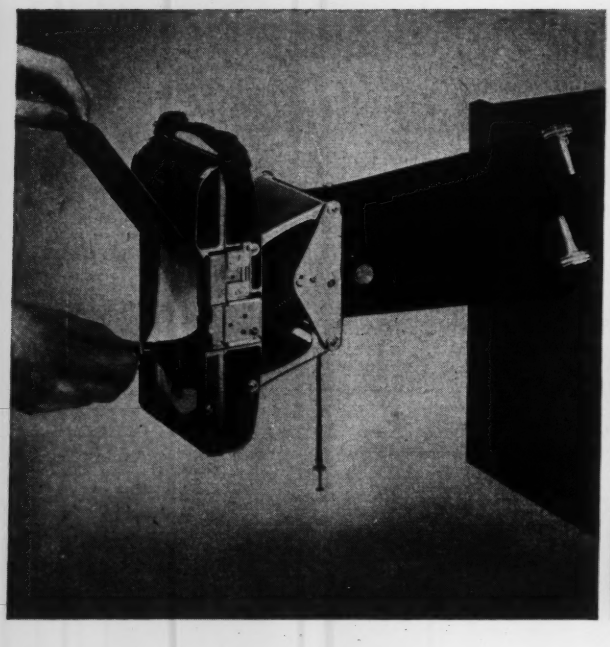


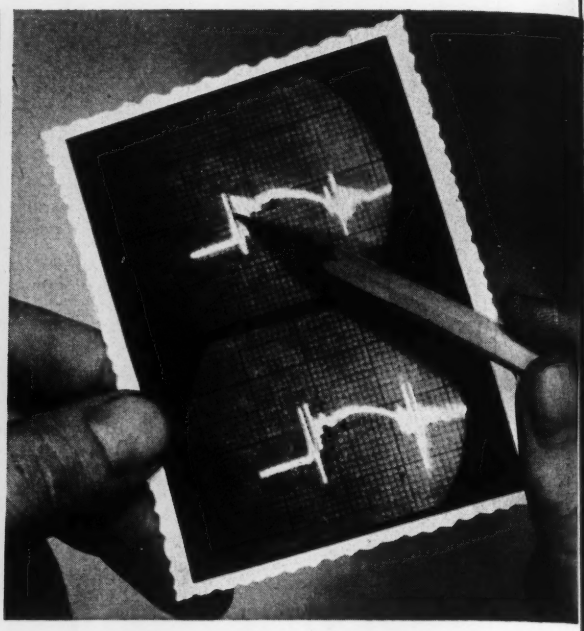
Write Dept. A-19 for free copy of Bulletin 618 giving details on these Brush instruments.

PUT IT IN WRITING WITH A BRUSH RECORDING ANALYZER

THE Brush DEVELOPMENT CO.

PIEZOELECTRIC CRYSTALS AND CERAMICS • MAGNETIC RECORDING
ELECTROACOUSTICS • ULTRASONICS • INDUSTRIAL & RESEARCH INSTRUMENTS





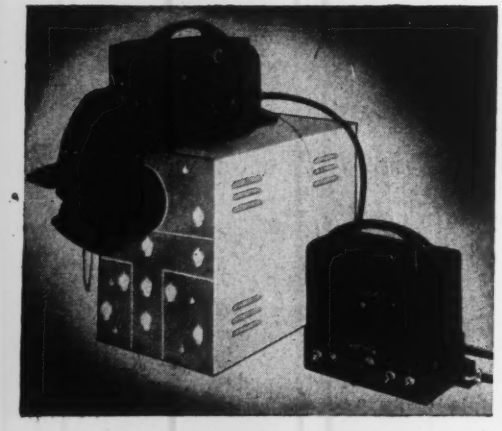
EASY TO TAKE...EASY TO READ

with the Fairchild-Polaroid® Oscilloscope Camera

ELECTRONIC CONTROL GIVES INFINITE SPEED VARIATION

with the Fairchild Oscillo-Record Camera

For both still and continuous-motion recording on 35-mm film or paper, the Fairchild Oscillo-Record Camera is ideal. Continuously variable speed control is provided through electronic regulation. There are no belts or pulleys. Film is sprocket-driven so there is no slippage. Top-of-scope mounting eliminates need for tripod and keeps scope controls easily accessible. There is provision for three film lengths—100, 400, or 1000 feet.



Fairchild's adaptation of the Polaroid-Land camera gives you more than just a fast photographic print of an oscilloscope image. The print is *exactly* half-size for easy measurement of values, especially when a grid is used. And you see the image exactly as it appears on the scope—not reversed. Each 3¼ x 4¼ print records two images.

Moreover, it takes only two minutes (less, if you're fast) to set up the camera, snap the shutter, and pull the tab. Then you wait one minute more and remove the finished print. It's as simple as 1-2-3. No focusing, no special training required.

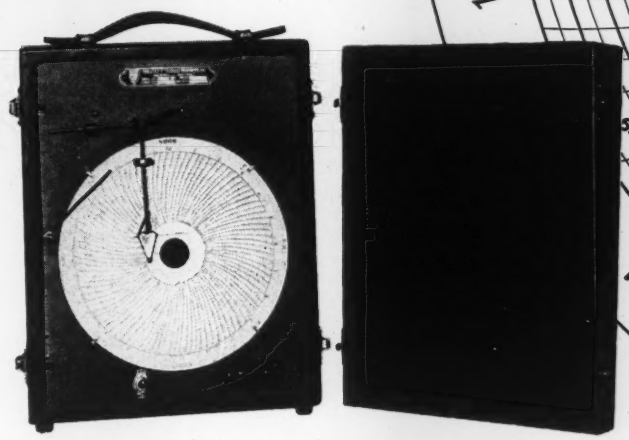
Full information about the Fairchild-Polaroid and Fairchild Oscillo-Record Cameras is available on request. Write today to *Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, New York, Department 120-17F.*

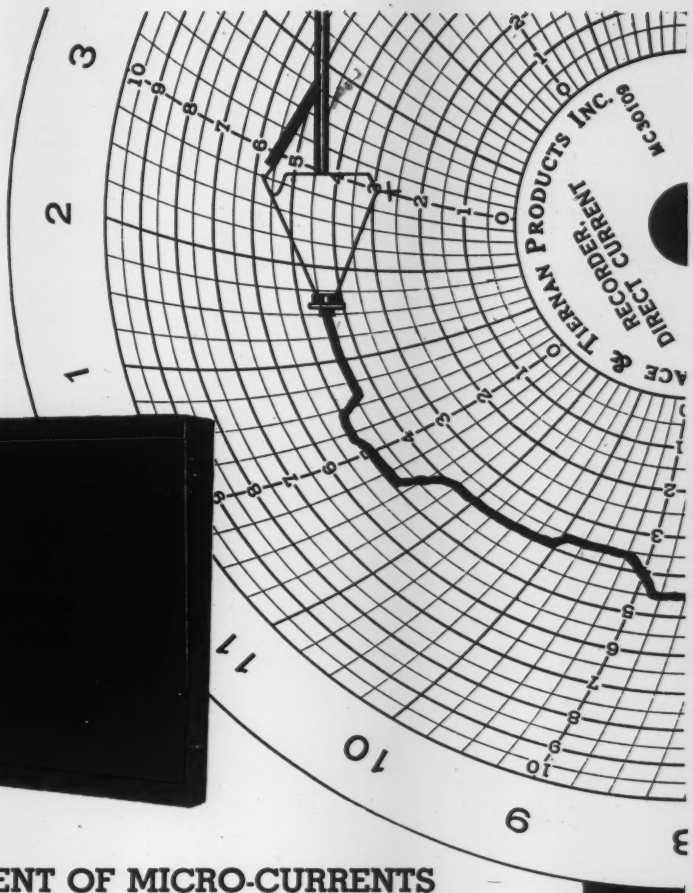
FAIRCHILD

OSCILLOSCOPE RECORDING CAMERAS

ANOTHER W&T PRECISION INSTRUMENT

THE PORTABLE DIRECT CURRENT RECORDER





FOR THE MEASUREMENT OF MICRO-CURRENTS

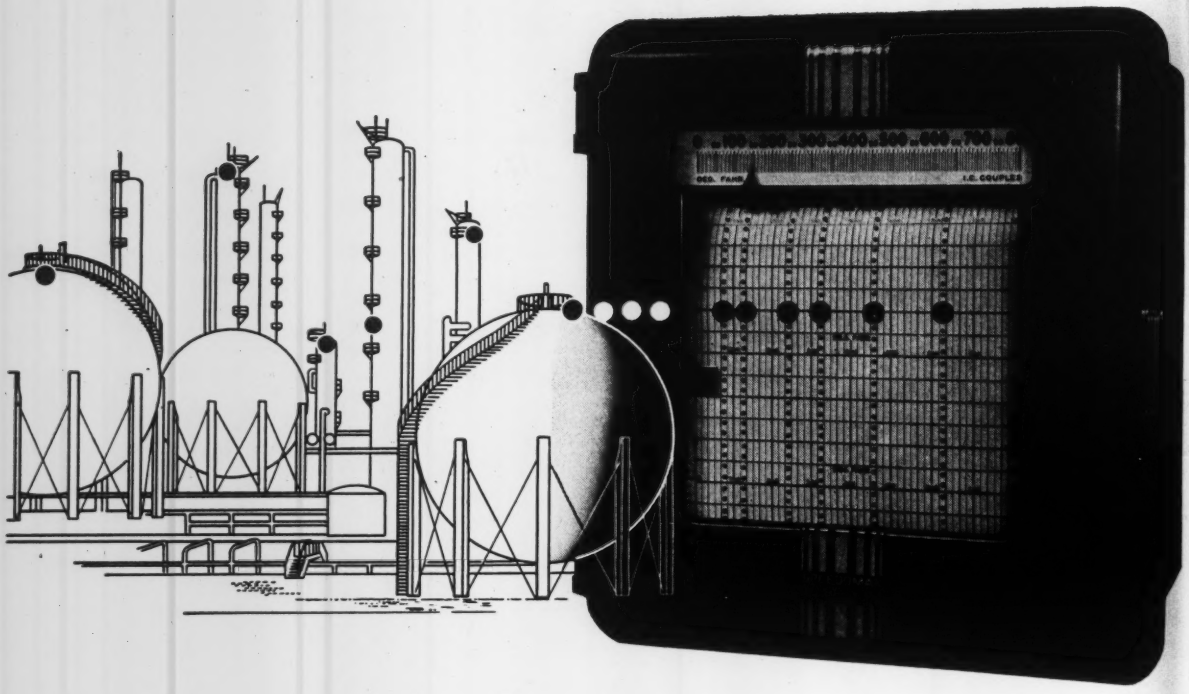
The New W&T Portable Direct Current Recorder permits direct recording of minute electrical currents and voltages, as well as certain non-electrical values through the use of pick-ups and amplifiers. The instrument is extremely versatile and possesses a range which permits handling 6.0 amperes and, at the same time, can detect a change of current as low as 1/10 microampere. It is useful in research laboratories and for such applications as communication and electronic circuit analysis, and in thermocouple pyrometry. Brief specifications are:

Type	Moving magnet, interchangeable coil.	Scale Length . .	2½ inches.
Sensitivity . . .	1 part in 1000 of full scale range.	Chart Diameter .	8 inches.
Minimum Range .	0 to 100 microamperes.	Chart Speed . .	1 revolution per 24 hours.
Maximum Range .	0 to 6.0 amperes.	Case	Highly finished hard wood.
Coil Adjusting Range . . .	2.3 to 25 ampere turns.	Size	13" high by 10⅛" wide by 5½" deep.
		Weight	10 pounds.

A-87

Write today for complete details—there's no obligation

WALLACE & TIERNAN
PRODUCTS, INC.
ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
Belleville 9, New Jersey • Represented in Principal Cities



A new temperature Fact every 2 sec!

Today, when many refinery operations may need temperature facts within seconds instead of minutes, the Speedomax story is worth knowing:

For a Speedomax Multiple-point instrument's record-printing "wheel" darts from temperature to temperature in just 2 seconds per point! Thus, if there are, say, 15 fairly important temperatures on a single refinery unit, each one can actually come up and be recorded as often as twice per minute, automatically and continuously.

Two extra checks for vital temps

But suppose a few points require even closer watching, or more frequent recording? Speedomax handles them, too, in either of two ways:

First, they can be recorded more frequently than the other points, in such a sequence as 1, 2, 1, 3, 1, 4, etc.

Second, the vital points can be recorded in greater detail than the other points. This is done by giving the instrument an additional range which is used only with the pre-selected points. This range puts far fewer degrees-per-inch across the instrument's scale; it thus "spreads" the reading for detail.

Ability to measure temperature from any source and across either wide ranges or the new narrow ranges is another L&N specialty. Selection among thermocouples, Thermohms and Rayotubes will determine the correct sensing element. Selection among various recorder components will put the information on paper in the desired form.

160 temps on one instrument

For these and many more features . . . for instance, 160-point models . . . credit Speedomax's refined, stable, dependable construction, both electrical and mechanical. Too, Speedomax is not affected by vibration; never needs levelling up; can measure many quantities besides temperature.

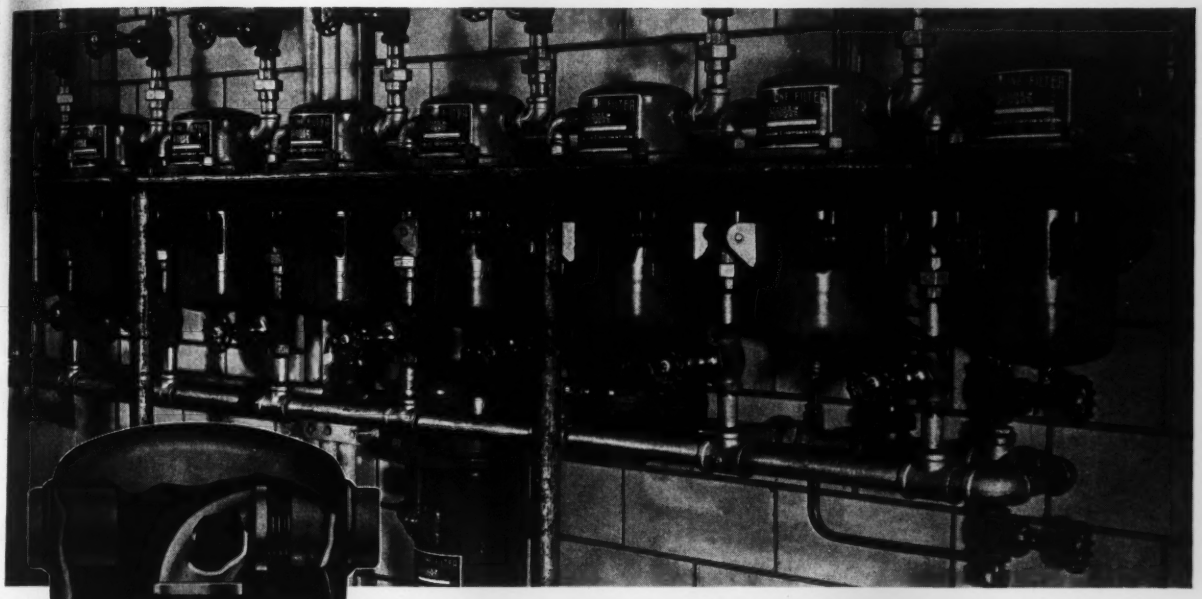
Any L&N office, including 4955 Stenton Ave., Phila. 44, Pa., will send the Speedomax story on request.

LEEDS NORTHRUP

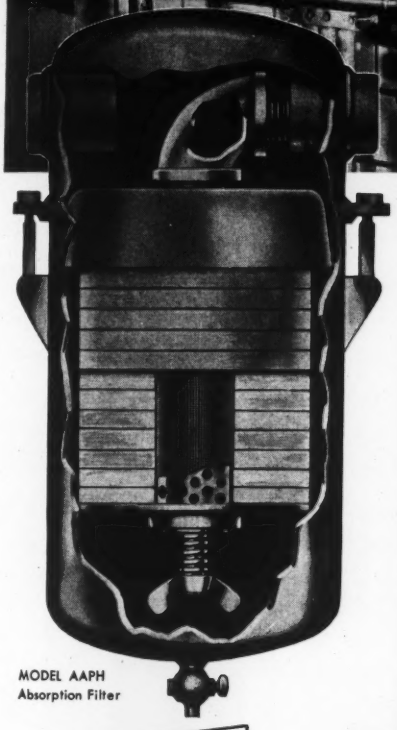
Jrl. Ad. ND46-700(2)

THESE STAYNEW ABSORPTION FILTERS

Protect Automatic Combustion Controls from All Oil, Moisture, Solids



Specially developed Staynew Filters guarantee clean, dry air for Boiler Controls at Rochester Gas & Electric Corp.



MODEL AAPH
Absorption Filter

The Rochester Gas & Electric's new automatic boiler controls needed *clean* air for efficient operation—air that's free of oil and moisture as well as solids. In order to accomplish this, coke and then charcoal filters were tried. An accumulation of oil continued to "gum up" the reducing valve feeding the master control. Our engineers were called in, and after thorough study, a special felt pad filter (shown at left) was developed and the new filters were installed. *Result*—no fouling has occurred in the control air system since the filters were installed in 1949.

If you have a special filtration problem call on Dollinger's experienced engineers. Write today for Bulletin B-1A.

Representatives in Principal Cities

DOLLINGER REG. PROTECTOMOTOR U.S. PAT. OFF. STAYNEW FILTERS

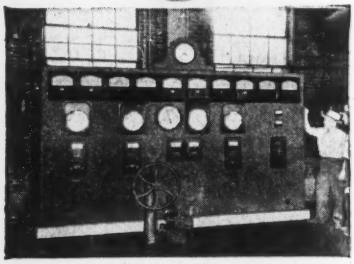
DOLLINGER CORPORATION

63 Centre Pk., Rochester 3, N. Y.

ALL TYPES OF FILTERS FOR EVERY INDUSTRIAL NEED

5 ways to use HAYS low pressure gages

1



Pressure and Flow Measurement in Gas Producer Plant. In this automatically controlled gas producing plant Hays FOT Indicators show gas header pressure, stack pressure, air pressure, and air flow. The FOT is a popular pressure-flow instrument in the process industries.

2

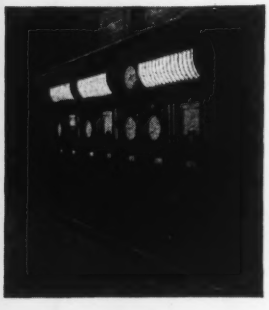
Resistance Measurement in Air Conditioning Systems. The Hays air filter gage is a money-saver when used to indicate the amount of resistance through filters in air circulating systems. When equipped with open or closed switches it flashes or sounds an alarm when resistance becomes excessive.

3

Commercial Boiler Testing Portable easily handled Hays "B" gages are widely used for checking draft in the combustion chambers of small automatically fired boilers to assure maximum efficiency. The scales are easily read—large black figures on a light background. Gages are compact, rugged.

4

Product Testing by Differential Pressure Measurement. Here the simplicity of the Hays FOT indicator makes possible testing of a complicated product by unskilled workers. Hays gages were selected because of their accuracy and because they could be supplied with large, easily read scales.



5

Continuous Draft Indication in Boiler Furnaces. Banks of Hays "V" gages are a familiar sight in thousands of boiler rooms. They provide an accurate "picture" of furnace draft conditions at any given moment and thus warn the operator of soot deposits, slag accumulations, too thin a fire, burned out baffling, etc.

HAYS has the most complete line of low pressure gages on the market.

● 4 diaphragm units available for both pressure and differential ● diaphragms of colon leather or of synthetic impregnated material highly resistant to corrosive atmospheres, moisture and oxidation ● 4 case sizes ● as many as 12 pointers in one case ● ranges from a minimum of .2" water to a maximum of 120" water ● for indicating, recording, or controlling draft pressure, differential or flow ● wall, lug, or flush mounting—also portable models ● interior or exterior illumination ● square root extractors available.

What's your draft or pressure problem?

Hays engineers are anxious to help you solve your low pressure measurement and gas or air flow problems. They have applied Hays gages to situations ranging from the determination of fuel oil level in marine vessels to the measurement of the density of mud in oil drilling operations. Send a description of your problem to Clarence Miller, The Hays Corporation, Michigan City, Indiana. You'll receive Hays' recommendations plus Bulletin 49-667 describing the complete line of low pressure instruments.

THE HAYS CORPORATION
MICHIGAN CITY 8, INDIANA

Automatic Combustion Control • Boiler Panels • Hays-Penn Flowmeters
Veriflow Meters and Veritrol • Gas Analyzers • Draft Gages
Combustion Test Sets • CO_2 Recorders • Electronic Oxygen Recorder

ALL RANGES WITH THIS ONE CONTROL

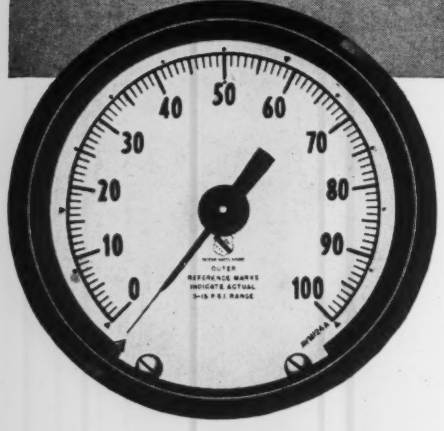
Model 630

Just *one* knob—extra large—easy to turn—flush with the panel, controls all ranges. This one knob saves your time—minimizes the chances of "burn-outs" because you don't have to remember to set another control. You can work fast with Model 630 with your eyes as well as your hands. Look at that scale—wide open—easy to read, accurately. Yes, this is a *smooth TV* tester. Fast, safe, no projecting knobs, or jacks, or meter case. Get your hand on that single control and you'll see why thousands of "Model 630's" are already in use in almost every kind of electrical testing

FOR THE MAN WHO TAKES PRIDE IN HIS WORK

Triplett

TRIPLETT ELECTRICAL INSTRUMENT COMPANY · BLUFFTON, OHIO, U.S.A.



Duplex *Receiver* Duragauge—3½" Dial Size. Peripheral pointer is red.

Compact panelboard design demands pressure gauges that combine extreme accuracy with smaller size, easy-to-read dials. *The new Ashcroft Receiver Duragauges, with 3½" dial, meet those requirements exactly.*

Wherever pneumatic transmission and control systems are used to indicate pressure, temperature or flow—in power plants, refineries, chemical plants—these new *Receiver* Duragauges provide *accuracy within ½ of 1 percent of the dial range.* Standard transmitted air pressure range is 3 to 15 P. S. I. Other ranges include 2 to 14, 2 to 15, 3 to 18 and 5 to 25 P. S. I.

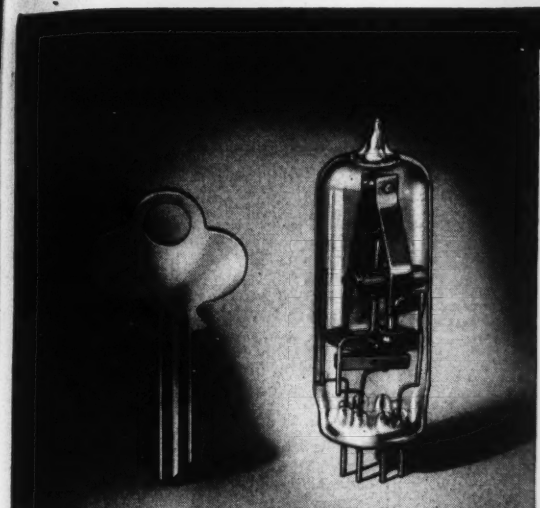
Single and Duplex *Receiver* Duragauges are available. The Duplex incorporates two separate sets of Bourdon tubes, movements and pointers. Bourdon tube material is heat-treated phosphor bronze, extra wide for extreme sensitivity, with long tip travel for precision accuracy.

Get complete data, including dimensions and standard graduations. Your Ashcroft Distributor will gladly help you select the right *Receiver* Duragauges for your specific needs.

ASHCROFT GAUGES

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONNECTICUT

MAKERS OF 'ASHCROFT' GAUGES, 'HANCOCK' VALVES, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN' INDUSTRIAL INSTRUMENTS. BUILDERS OF "SHAW-BOX" CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.



SCARCELY LARGER THAN YOUR DOOR KEY

FOR . . .

Cathode Protection
Gyro Erection
Motor Starting
Integration
Holdovers
Overload Protection
Current Interruptions (Flashers)
Cycling Durations
Emergency Circuit Switchovers

Announcing . . . a NEW Miniature by EDISON

EDISON announces its new Model 207 Miniature Thermal Relay — designed to meet the need for a space-saving time-delay relay.

Into the design and development of this sealed-in-glass miniature, EDISON has applied the experience of over 20 years in the thermal engineering field and has built into it many of the quality features of the widely-used EDISON Model 501 Thermal Relay. In numerous applications the two relays have similar operating characteristics.

Pilot production started in December 1951. For free bulletin, just clip coupon and mail.

SPECIFICATIONS • MODEL 207

- Sealed-in-glass
- Arc quenching atmosphere
- Precision timing — Final adjustment made *after* sealing by patented feature
- Weight: ½ oz. (approx.)
- Diameter: ¾" (approx.)
- Height: 2¼" maximum (seated)
- Standard Heater Voltages: 115v, 27.5v, 6.3v
- Contact Ratings: 2.5 amps @ 125v ac., 1.0 amp @ 125v dc.
- Ambient Compensation: −60 to +85°C
- Nominal Heater Input: 2 watts

Mounting: Miniature Button 7-pin
Range of Delay Periods: 5 secs. to 120 secs.

OTHER INSTRUMENT DIVISION PRODUCTS

Sealed Thermostats
Sensitive Relays
Temperature Monitors
Electrical Resistance Bulbs

YOU CAN ALWAYS RELY ON EDISON

Thomas A Edison
INCORPORATED
Instrument Division • West Orange, N. J.

To: Instrument Division, THOMAS A. EDISON, INC.
63 Lakeside Avenue, West Orange, New Jersey

We may have an application for your Miniature Thermal Relay to_____

Please send bulletin I3 to:_____
Name and title_____
Company_____
Address_____

HOW TO

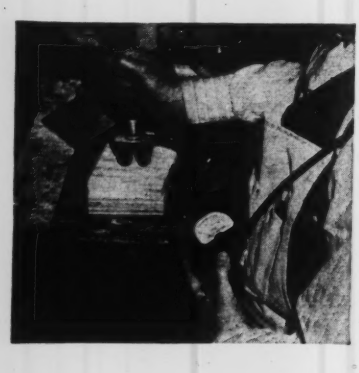
MEASURE MOISTURE

MOST ACCURATELY... MOST EASILY

For all-purpose duty—

TAG MOISTURONIC METER

No other moisture meter has all the advantages of the Tag Model 8008 Moisturonic—the only moisture meter that measures up to 150% wood moisture. It's dependable, of course—like all Tag and Weston instruments. It's as easy to operate as top-rank engineering intelligence has been able to make it. It weighs only about 10 pounds—has a sturdy, comfortable carrying strap. Fine quality in appearance as well as performance. Both battery and A-C types. Write today for Bulletin TT10 giving full description and technical details.



For utmost portability—

TAG MIDGET MOISTURE METER

The Tag Midget is smaller and more accurate than any other portable-type moisture meter—there's longer experience behind it. Weighs less than 4 pounds. Operates on standard dry cell inside. Instantly indicates per cent moisture. Is calibrated for wood and plastic; can be adapted for other materials. For details, write for Bulletin 1295.

8429

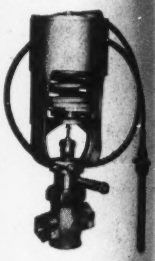
TAG TAGLIABUE INSTRUMENTS DIVISION WESTON

WESTON ELECTRICAL INSTRUMENT CORPORATION

614 Frelinghuysen Avenue, Newark 5, New Jersey

Self-Operating Controllers Hold Precise Temperatures

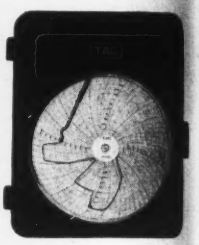
Temperatures between the limits of 20 and 300°F. are accurately maintained by the line of Self-Operating Controllers manufactured by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. These controllers are entirely self-contained, requiring no connection to any air or electrical power supply.



Available in styles for use on steam, hot water or refrigerant lines, TAG Self-Operating Controllers continuously adjust the supply of heating or cooling medium to maintain constant temperature despite changing thermal conditions. Typical applications include water heaters, tanks, retorts, washers, driers and pasteurizers.

"TAG" Temperature Recorders Chart from −300° to +1000°F.

Accurate written records of varying temperatures are charted by the Temperature Recorders produced by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. Temperatures as low as −300°F. or as high as +1000°F. can be recorded with these versatile instruments.



Various types of actuations in TAG Temperature Recorders achieve scale expansion for utmost precision over the working ranges. Interchangeable tube systems are laboratory calibrated at the factory. A safety link provides over-range protection. Details are given in Catalog 1210.

"TAG" Glass Thermometers Provide Lasting Precision

Accurate general purpose and laboratory thermometers are supplied by TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., Newark 5, N. J. Available armored or unarmored, these individually etched stem thermometers indicate temperatures as low as —150° or as high as 950°F. in the standard grade, and values as low as —30°F. or as high as 750°F. in the extreme precision grade. Limited range thermometers graduated to 1/100°C., for calorimeter use, are also standard.

In addition to individual instruments, matched sets of A.S.T.M. Testing Thermometers, with overlapping ranges spanning temperatures from —36°F. to 760°F., or —38 to 405°C., are available in convenient simulated leather cases.

ROUND AND SHAPED TUBING
(.010" to ⅜" O.D. Max. Certain Analyses .035" max. wall to 1⅜" O.D.) Available in:
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A.I.S.I.—C-1008, MT-1010, MT-1015, C-1118, MT-1020, C-1025, C-1035, E-1095
Alloy Steels:
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Stainless Steels:
A.I.S.I.—303, 304, 305, 309, 310, 316, 317, 321, 347, 403, 410, 420, 430, 446, T-5
Nickel Alloys:
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The HOLE Story —by— Superior
Chapter 2
The Bubble That Beats Trouble to the Punch
In science, the arts and industry, fine small tubing serves many purposes, from the hypodermic injection of healing drugs to the control of hydraulic presses that produce airplane and tank components.
In every tubing job there is one prime requirement. The tube must not leak. Here at Superior we specialize in the production of high quality tubing in all practical metals . . . and we use many methods to insure the superiority of our product.
Precision gauges in the hands of experienced inspectors check for dimensional precision. High powered microscopes in our laboratories investigate grain structure. Chemical analysis maintains close control on metallurgy. And in our shops compressed air, under pressures to hundreds of pounds per square inch, is forced into tubing held under water to make sure that leaks are detected and eliminated.
The whole story of Superior is one of quality . . . in machines and methods, in men, and in the end result —fine small tubing to do tough jobs well.
This is a story with continuity, for our aim holds always to raise the standards by which we judge Superior tubing . . . and to continue to increase the rate at which we produce it to meet your demands.
SUPERIOR TUBE COMPANY, 1968 Germantown Ave., Norristown, Pa.
West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. UNderhill 0-1331.
Superior
THE BIG NAME IN SMALL TUBING
All analyses .010" to ⅜" O.D.
Certain analyses (.035" max. wall)
Up to 1⅜" O.D.

MAGNETRON
PERMANENT MAGNETS AND ASSEMBLIES

with

- ☆ ***Die Cast Aluminum Jackets***
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- ☆ ***Celastic Covers***

Complete assemblies with Permendur, steel or aluminum bases, inserts and keepers as specified. Magnetized and stabilized as required.

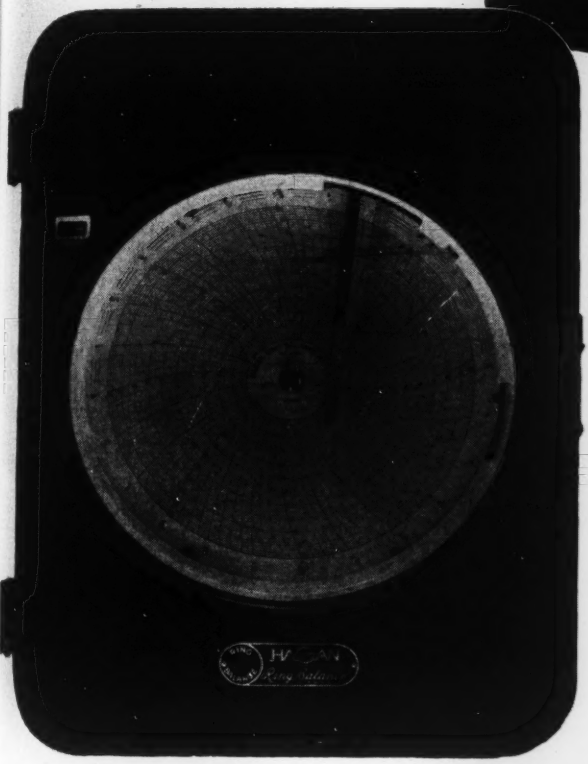
THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois

No stuffing box troubles in

HAGAN RING BALANCE METERS



because there are no stuffing boxes!

Forget about stuffing box troubles and pressure tight bearings when you install Hagan Ring Balance Meters. The simple, flexible S-tube connections to the ring assure dependable accuracy and trouble-free operation.

Features of the Hagan Ring Balance Meter include:

- **Calibration can be checked under operating conditions by check-weight method**
- **Excellent response at extremely low flow rates**
- **Mercury level not critical**
- **Full-scale chart differential is adjustable over a 7-to-1 range**

HAGAN CORPORATION

HAGAN BUILDING
PITTSBURGH 30, PENNSYLVANIA

Our engineers will be glad to show you how Hagan Ring Balance Meters can help solve your metering problems. Use the coupon, or write to Hagan Corporation, Hagan Building, Pittsburgh 30, Pa.

Hagan Corporation
Hagan Building • Pittsburgh 30, Pennsylvania

Please send me further information on Hagan Ring Balance Meters. I am particularly interested in .....

.....

NAME .....

POSITION .....

COMPANY .....

STREET AND NUMBER .....

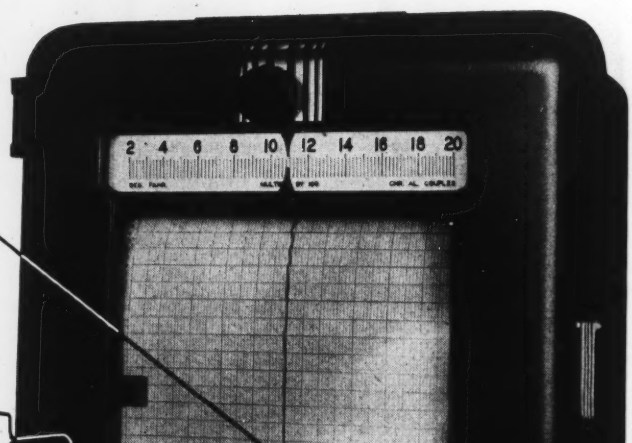
CITY ..... ZONE ..... STATE .....

I-2

TEMPERATURE CONTROL

Matched to your plant's

FURNACE PRODUCT PRODUCTION



Need to get more work out of your furnaces and ovens? The pyrometer that fits the heating equipment, the product and the production need can do a great deal to turn out more tonnage, and also more that meets specifications.

Two Types of Control

The secret of successful automatic control is very simple; just turn the heat up and down in the particular way the furnace and product prefer. And there are only two general ways: On-Off Control, and Three-Function Control.

On-Off Control Can't "Think"

On-Off Control turns the fuel all the way up when temperature drops to a predetermined low point; turns it all the way down again at the specified high point. Temperature will of course undershoot and overshoot; when cycling is inside bounds, this simple control is very popular.

Three-Function Control Can "Think"

Instead of turning fuel up and down at preset limits, three-function control in effect, keeps looking at temperature trends. If they are trying to get out of hand, the Controller heads them off. This "thinking" is done in three ways:

1. Fuel is turned up and down in proportion to the furnace's heat change. (Function one)

2. If the furnace doesn't respond when the fuel is changed, the instrument waits a little—moves the valve again—keeps this up until the furnace does respond. (Function two)

3. If the temperature jumps, as when a heated charge is removed or a fresh charge put into a furnace, the speed of the resulting change can be considered by the Controller. (Function three)

User Tunes the Control

By turning dials on the control pyrometer, the user tunes the three functions to the process: he simply uses his common sense and experience. A big benefit is thus: that every furnace control can be tuned by the best-qualified man in the plant.

Further information on request; contact nearest L&N office or 4955 Stenton Ave., Phila. 44, Pa.

LEEDS NORTHRUP

Jrl. Ad. N-33(52a)

Guest Editorial

Trends in Design of Laboratory Apparatus

By Dr. A. O. BECKMAN, President, Beckman Instruments, Inc.*

FORECASTING the trends of future apparatus design and development is an essential part of any apparatus manufacturer's business, and errors in forecasting can have dire consequences. I hope, therefore, that my crystal ball is free from distortion and that it will give a true preview of future trends in the design and development of laboratory apparatus, particularly the short-term trends.

Factors Which Influence Apparatus Development

The factors which have influenced apparatus design and development in the past, and which will continue to exert their influence in the future, include industrial expansion, recognition of research, manpower problems, and defense activities. Let us examine these factors.

Industrial Expansion

One important factor is the tremendous expansion of certain industries, notably the chemical and electronics industries. One does not need financial statistics, growth curves, and a profound understanding of industrial economics to ascertain the influence of industrial expansion on laboratory apparatus. One needs merely to compare a 1920 laboratory-supply catalog with the 1951 edition to see the difference in the character of the apparatus. Beakers and balances are much the same; what stands out is the large number of new instruments.

Instruments have infiltrated into all types of laboratory operation—from the routine control laboratory to the most advanced research laboratory. Probably without our being really aware of what has been happening, instruments have revolutionized laboratory methods. Industrial expansion has contributed in large measure to this revolution both by creating needs for new instruments and by providing a market sufficiently large to justify the development of new instruments.

The electronics industry has had a profound effect on apparatus development by providing an entirely new technical approach to the problems of the laboratory. It is unnecessary to remind you that most of the major advances in modern laboratory apparatus would not have been made without electronics.

Recognition of Research

As industry expanded there was a corresponding expansion of laboratory facilities for testing and for process control. More important, from the standpoint of apparatus development, was the growth of the research laboratory, especially the industrial research laboratory. At the time of World War I only the larger industrial organizations maintained research laboratories of substantial size. Even as recently as the middle twenties many industrial concerns looked upon a research laboratory as a luxury which could be indulged in only for the sake of "keeping up with the Joneses." Long before World War II, however, the tremendous strides made by companies with good research facilities changed the status of the research laboratory from that of a luxury, to be indulged in only when profit permitted, to that of one of the most essential phases of a company's operations. Such statements as: "Most of our profit comes from products not in existence ten years ago" are now common.

Research called for new tools. Modern research problems required measurements of properties not previously important; accuracies not previously needed. Investigators at the frontiers of science opened up entirely new fields for observation and measurement. Interest spread from the molecule and the atom to the electron and the nucleus—and then to the fragments of nucleus which result from nuclear fissions. Fantastic techniques were devised, involving quantities of material so small as to be practically incomprehensible in terms of pre-war thinking. Human brains and fingers were too slow for the mathematical problems which arose, so electronic computers were devised which solve in a fraction of a second problems which otherwise would require hours or days.

Research is playing a role of ever-increasing importance in human affairs, and I can detect no signs which indicate any decrease in research activity in the near future. On the contrary, all indications are that research activities will expand. Note the number of new research laboratories which have recently been built or are now being built, even in this time of material shortages. Note the increase in research budgets. (One factor in increased research budgets, of course, is the new 18-cent dollar. So long as the excess profit tax continues, we may expect greater division of earnings into research and other business activities which hold promise of long-range benefits.) Note especially, however, the change in attitude toward research. Research is no longer a luxury, it is a necessity. Research is still a gamble; by its very nature it must always remain a gamble because it deals with the unknown. Unlike most gambles, however, research usually pays off handsomely. This fact is well known today, not only to research investigators but to industrialists and economists, even to the man on the street.

Anyone who has ever engaged in research knows that research is an endless process. The solution of one problem usually discloses many other problems, equal in interest to the original one. Research, therefore, is autocatalytic: it is a chain reaction. Unquestionably, expanding research activities will result in increasing sales of research equipment. Further, the inevitable progress of research will create the need for new types of laboratory instruments. Every apparatus manufacturer who hopes to improve or even maintain his position in the industry, must be alert to the change and must be willing and able to change his products to fit the ever-changing requirements of science and industry.

It seems safe to predict that the requirements of research will play a dominating role in the determination of what is

Continued on page 219

* Presented at the Midyear Meeting, SAMA, Nov. 28, 1951, Hotel New Yorker, New York, N. Y.

You Can Help

AN important part of the message in the guest editorial on this page is the fact that the field of industrial instrumentation is growing rapidly and is using "scientific" instrumentation at an ever-increasing rate. Along with this growth is the growth in number of "instrument men"—men who use, buy, design, install, and maintain instruments.

You can help sustain this healthy growth. Do you know anybody who is now working in the field of instrumentation and who does not receive *Instruments*? Do you know anybody who needs better perspective and more technical information about mechanical, pneumatic, hydraulic, optical, chemical, electrical, or electronic instrumentation? Send us his name. We will send a sample copy of *Instruments*, with your compliments.

Not only will your colleagues thank you, but you will contribute to the continuous growth of your field and your magazine. *Turn to the form on page* 174.

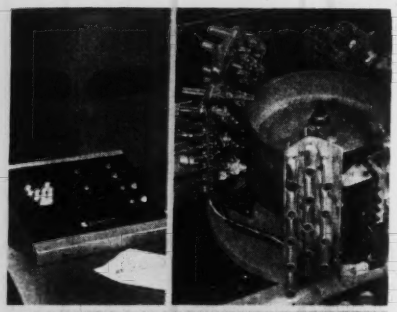
The Month's NEW INSTRUMENTS

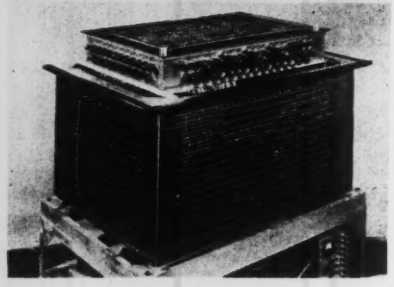
In this department we report each month new devices for measurement, inspection, testing, computing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 237

General-purpose computer

New "CRC 102" or "Cadac" computer is digital computer for solving arithmetic or mathematical problems. Features include small size and high reliability. Total number of vacuum tubes is 195. Weight is less than 500 lbs. Dimensions are 3½ x 2¼ x 4¼ ft. plus small control panel. Operates on 110



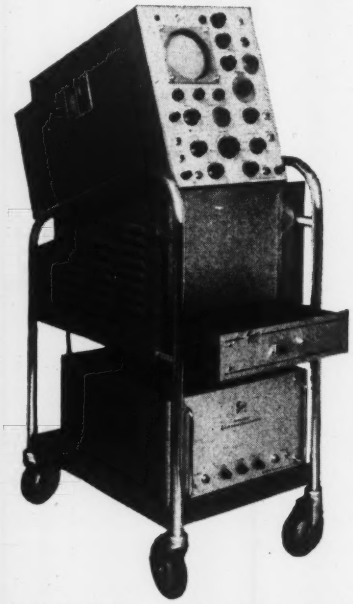


volts, 60 cycles, 30 amp. Magnetic-drum memory can store 1023 words; drum rotation speed is 40 rps. Conventional 3 address code commands available are: add, subtract, multiply, divide, shift, compare (transfer control), extract, halt, print, tape. Input-output facilities are electric typewriter and keyboard. Typewriter is under control of computer's print commands. Can be used with magnetic-tape unit.—*Computer Research Corp., 3348 West El Segundo Blvd., Hawthorne, Calif.*

Mention No. 201 when filling out card.

Oscilloscope

New "Type 517" cathode-ray oscilloscope is designed for observation and recording of fast-rising waveforms. Fixed sweeps of 10, 20, 50, 100, 200, 500 m usec./cm., and 1, 2, 5, 10, 20 usec./cm. are provided. Amplitude calibrator provides voltages from 0.15 to 50 v. full scale. Distributed-type vertical amplifiers provide rise time of 0.007 usec. with maximum sensitivity of 0.1 v./cm. Time delay in vertical amplifier permits viewing leading edge of waveform that triggers sweep. Accelerating



potential of 24 kv. permits photographic recording of single sweeps. Cathode-follower outputs, calibrator voltage, and gate waveform are available on front panel.—*Tektronix, Inc., P.O. Box 831, Portland 7, Ore.*

Mention No. 202 when filling out card.

Oscilloscope

New "Model 3441" 5-inch oscilloscope has illuminated calibration meter for calibrating and reading peak-to-peak voltage from 0 to 1000 volts. Horizontal

amplifier is flat from 20 cps. to 150 kc.; deflection sensitivity is 0.15 rms. v./in. Vertical amplifier has response to 4 Mc. and sensitivity of 0.01 rms. v./in.—*The Triplett Electrical Instrument Co., Bluffton, Ohio.*

Mention No. 203 when filling out card.

Mass Spectrometer

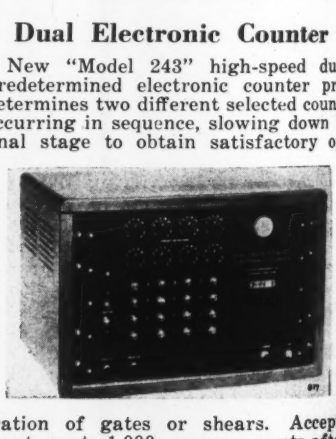
New "Model 21-401" dual-purpose mass spectrometer is designed for analysis of mixtures of gases and light liquids, and ratios of stable isotopes. Uses no refrigerants. Has mass range of 2 to 100, with automatic scanning

and recording of spectra from mass 12 to 100. Fifteen or more complete runs can be made in 8-hr. shift. Dynamic recording range is 300,000 to 1. For isotope-ratio work, first three decimal places are obtained from decade dials, last three from pen-and-ink record.—*Consolidated Engineering Corp., 300 N. Sierra Madre Villa, Pasadena 8, Calif.*

Mention No. 204 when filling out card.

Dual Electronic Counter

New "Model 243" high-speed dual predetermined electronic counter predetermines two different selected counts occurring in sequence, slowing down in final stage to obtain satisfactory op-

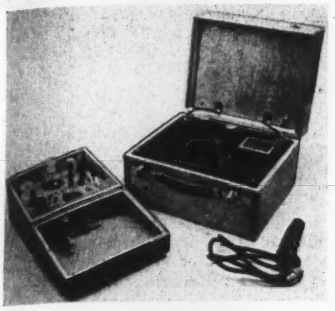


eration of gates or shears. Accepts counts up to 1,000 per sec.; resets after each output operation. Any two numbers from 1 to 9,999 may be chosen as control actuation points. Can be supplied to program sequence of control operations.—*Potter Instrument Co., 115 Cutter Mill Rd., Great Neck, N. Y.*

Mention No. 205 when filling out card.

pH Meter

New "Philips Universal pH Meter" provides accuracy of 0.01 pH or 0.5 mv.; range of 0 to 14.15 pH and 0 to 1415 mv.; currentless measuring with no polarization; zero indication by cathode-



ray tube; can be used with glass, quinhydrone, hydrogen, and platina electrodes. Has removable calomel and glass electrode. Controls correct for temperature. Uses built-in cadmium standard cell and 60-cycle a-c. power. Weight is 46 lbs.—*Research & Control Instruments Div., North American Philips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y.*

Mention No. 206 when filling out card.

Double-pulse Generator

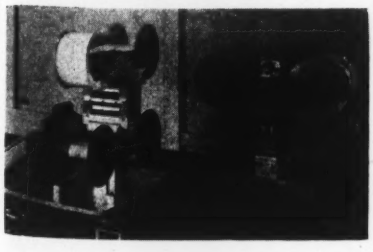
New "Model 903 Double Pulse Generator" produces either single or double pulses with variable amplitude and width, and variable spacing between

pulses from 0 to 10 microseconds. Pulse width is variable from 0.1 to 1.8 microseconds. Rep. rate from 1 to 1000 pulses per second. A 30-volt positive scope trigger occurs one microsecond before first pulse.—*Berkeley Scientific Corp., 2200 Wright Ave., Richmond, Calif.*

Mention No. 207 when filling out card.

Robot Machinist

New automatic machine-controller that can operate a machine tool remotely comprises a paper-tape perforator, and a sensor that translates the tape message into electrical impulses. The signals actuate synchro motors

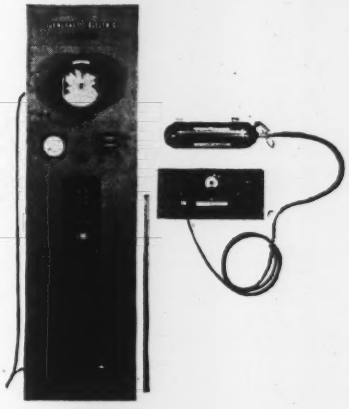


which control machine tools. Perforations in tape represent essential dimensions on blueprint. Tape controls sensor contacts to complete and break electrical circuits. Only manpower needed is for loading and unloading work and to check dimension periodically. Applications are in automatic and mass-production factories.—*Daco Machine and Tool Co., Brooklyn, N. Y.*

Mention No. 208 when filling out card.

Gamma-radiation Monitor

New "Area Health Monitor" detects and records gamma radiations in area and sounds alarm when tolerance limits are exceeded. Provides instantaneous radiation, total radiation in any

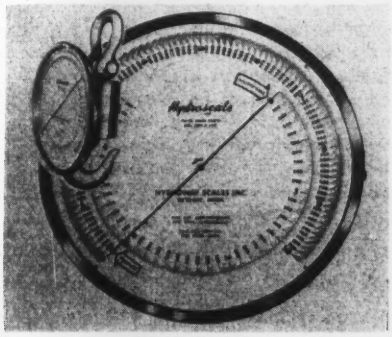


period, and 30-day integrated record of radiation in 15-min. intervals. Radiation rate can be telemetered to remote stations. Equipment consists of air wall ionization chamber, d-c. amplifier, and 6-ft. panel. Panel has torque-balance converter, watthour-meter mechanism, rate indicator, cyclometer counter, and recording device. Range is 1/2 to 5 times tolerance. Accuracy is 10 percent. Operates on 60 cycles, 115 volts.—*Meter and Instrument Dep't, General Electric, Schenectady 5, N. Y.*

Mention No. 209 when filling out card.

Hydraulic Crane Scale

New "Hydroscale" indicates weights in both kilograms and pounds. Uses hydraulic mechanism, tare adjustment for net load indication, and optional

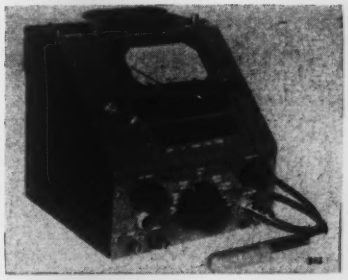


tilt face dial for high level reading. Available with dial diam. of 24 and 30 inches and in 5, 10, and 20 ton capacities.—*Hydroway Scales, Inc., 20624 W. Eight Mile Rd., Detroit 19, Mich.*

Mention No. 210 when filling out card.

High-frequency VTVM

New "Model 161-A" vacuum-tube voltmeter features frequency range from 60 cps. to 700 Mc. Seven d-c. volt ranges are from 1 to 1,000 v. full scale;

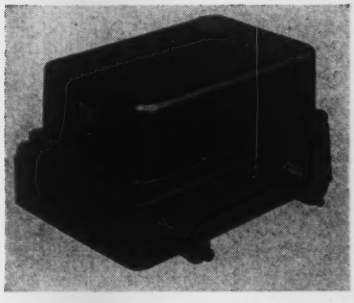


six a-c. volt ranges are from 1 to 300 v. Resistance readings from 0.1 ohm to 1,000 megohms are possible. Overall accuracy is 3 percent. D-c. input resistance is constant at 43 megohms; at 60 cycles, input impedance is 7-megohm resistance shunted by 1.3 uuf. Weight is 8.5 lbs.—*Electronic Measurements Co., Red Bank, N. J.*

Mention No. 211 when filling out card.

Double-pass Monochromator

New "Model 99 Double Pass Monochromator" provides pure source of chopped monochromatic light with high efficiency of double-monochromator sys-

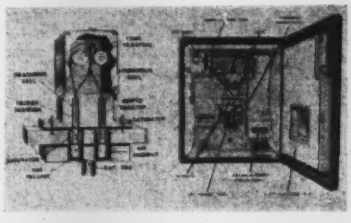


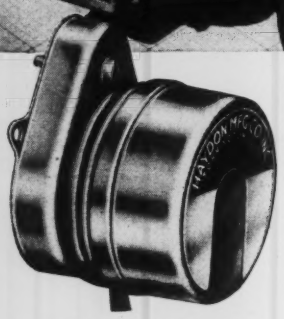
tem, but at cost of single-monochromator system. Radiation is reflected twice through same optical system, hence "double pass." Usable from 2000 Angstroms to 40 microns with suitable prisms. Resolution is better than 0.5 Angstrom at 2500 Angstroms. Dimensions are 14 x 14 x 9 in.—*Perkin-Elmer Corp., Norwalk, Conn.*

Mention No. 212 when filling out card.

CO_2 Recorder

New "Condu-Therm" CO_2 recorder uses thermal-conductivity principle of gas analysis. Gas flows through gas passage and diffuses through saturator into measuring cell. Gas in cell conducts





400 Cycle Motor

SYNCHRONOUS TIMING MOTORS and TIMERS for

- *Industrial*
- *Military*
- *Commercial Uses*

HAYDON* research and engineering staffs constantly seek to develop new and build better products. One example is the HAYDON 400 cycle timing motor. This is an hysteresis type synchronous timing motor, for use as a separate motor or in many different types of timers. HAYDON personnel and plant are equipped to build motors and timers using D.C., 60 cycle or 400 cycle for military or civilian applications.

HAYDON manufactures a wide range of dependable timing motors notable for their small size; quiet operation; total enclosure; separate systems for controlled lubrication of rotor and gear train; ability to operate in any position. Standard speed range from 60 rpm to one revolution in 7 days. The HAYDON motor is the basic element for standard timing components and custom-engineered timers designed and manufactured by the company for volume applications.

DESIGN INFORMATION

HAYDON will gladly send you technical data on request.

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HAYDON Manufacturing Co., Inc.

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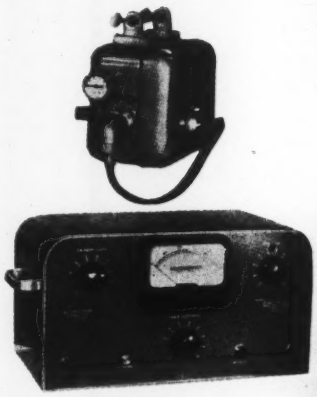
heat from heated resistor, which changes resistance. Air in comparison cell is used as constant reference. Resistors are in bridge circuit of analyzer. Small volume of gas in analyzing cell permits 5-sec. response to changes in CO_2 content. Accuracy is 0.25 percent for chart ranges up to 0 to 20 percent CO_2. Ruggedly constructed for boiler-plant use.—*The Hays Corp., Michigan City, Ind.*

Mention No. 213 when filling out card.

Infrared CO_2 Analyzer

New analyzer, which uses infrared bands absorbed by CO_2 content of gas, consists of explosion-proof pickup and electronic unit. Infrared emitted by



two nichrome sources in pickup is chopped. One infrared path is through reference cell; other is through sample cell and into detector cell. Standard units have 0 to 15 percent CO_2 full scale. Normal accuracy is 0.2 percent. Response is 90 percent of scale in 1/3 sec. Output is meter or output jack which supplies 5 ma. at 500 ohms for standard recorder.— *Liston-Becker Instrument Co., 20 Beckley Ave., Stamford, Conn.*

Mention No. 214 when filling out card.

Klystron Power Supply

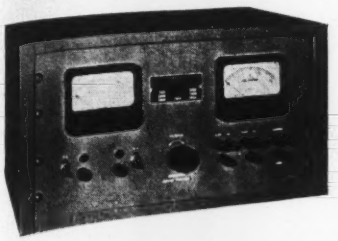
New "Model KX" Klystron power supply provides either 300, 400, 1000 or 1250 volts negative at high current. A 600-volt supply at 18 ma. provides

repeller bias. Drives positive grid bias Klystron tubes. Has low ripple.—*Polarad Electronics Corp., 100 Metropolitan Ave., Brooklyn 11, N. Y.*

Mention No. 215 when filling out card.

Power Supplies

New line of eight standard electronic power supplies vary in rating from 100 to 500 ma. and from 200 to 1,000 volts; bias voltages are either 0 to 150 volts,

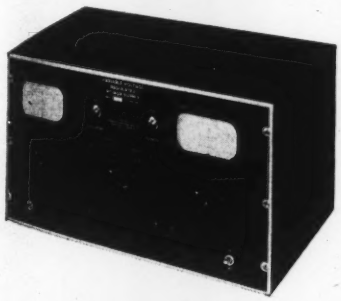


or 0 to 300 volts at 5 ma.; filament output voltage is 6.3 volts at either 3, 6, or 10 amp. Percentage regulation is 0.5 percent, and ripple voltage is 5 millivolts.—*Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.*

Mention No. 216 when filling out card.

Dual Regulated Power Supply

New "Model D6" heavy-duty supply provides two regulated outputs variable from 0 to 600 v. at a max. current of 200 ma. each, with regulation better



than 0.5 percent and ripple less than 10 mv. Knob combines two outputs to give max. output of 400 ma. Other outputs are 6.3 v. a.c. at 10 amp. center-tapped, 650 v. d.c. unregulated with less than 2 volts ripple, 0 to 150 v. d.c. at 5 ma. variable and stabilized. Voltmeter and milliameter monitor outputs. —*Oregon Electronic Mfg. Co., 2232 E. Burnside St., Portland 15, Ore.*

Mention No. 217 when filling out card.

Regulated Power Supply

New "Model A3" regulated power supply features continuously variable d-c. output from 0 to 400 v. with 0.5-

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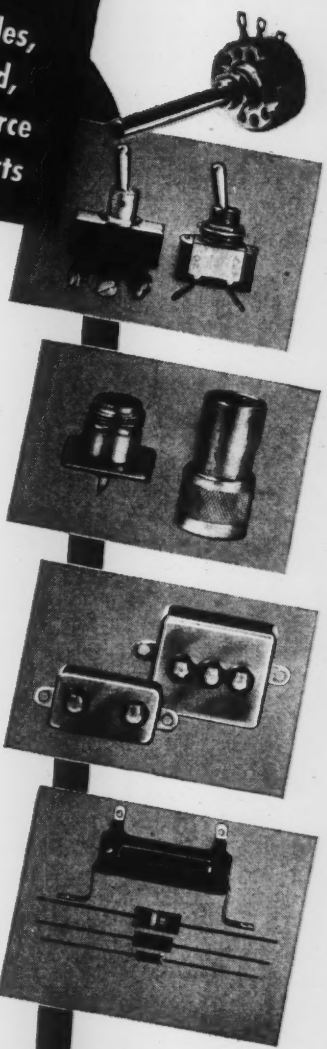
5 great stock-piles, strategically located, offer unsurpassed source for JAN component parts



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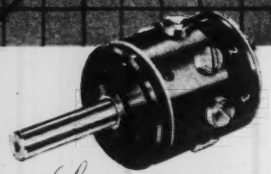
potentiometers



Synchromount

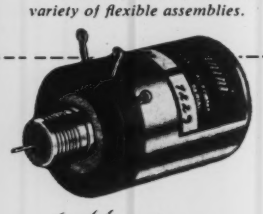
Linear and functional output, rugged construction, ball bearings, small size, low torque, synchro-type mount.

Rectipot

Push-pull motion, linear and functional output, high resolution, rectilinear potentiometer.

Jangpot

Functional and linear outputs, coils independently adjustable, variety of flexible assemblies.



Microtorque

Linear output, minimum torque, potentiometer and selsyn outputs, most ultra sensitive of them all.

These potentiometers are available in a variety of resistance values and circuits. For details on these and other fine instruments, write:

G. M. GIANNINI & CO., INC.
Pasadena 1, Calif.

Giannini

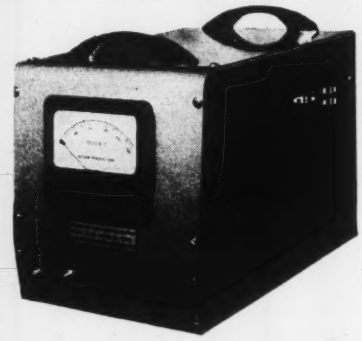
NEW INSTRUMENTS

percent regulation at loads from 0 to 200 ma. Other outputs are 400 v. d-c. unregulated, 0 to 150 v. d-c. stabilized, and 6.3 v. a-c. at 5 amp. Output ripple voltage is less than 10 mv. Meters monitor output voltage and current.—*Oregon Electronic Mfg. Co., 2232 E. Burnside St., Portland 15, Ore.*

Mention No. 218 when filling out card.

Regulated High-voltage Supply

New "VS-2A" regulated high-voltage supply has conventional full-wave-rectifier with pi-section filter to supply 350-v.d.c. and a single-tube circuit as

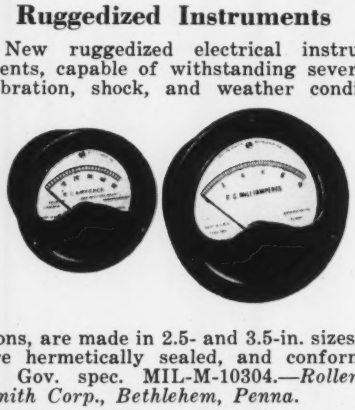


a generator of high voltage. High voltage d.c. is fed to feedback stabilizing circuit, which permits continuous wide-range selection of high voltage from 300 to 2500 v.d.c. Output voltage at 2500 volts, is stabilized to 0.01 percent (with 1.0-ma. load) and to 0.001 percent for a 100-ua. load. Ripple is less than 0.1 v. at 2500 v.—*Nuclear Research Corp., 2563 Grays Ferry Ave., Philadelphia 43, Penna.*

Mention No. 219 when filling out card.

Ruggedized Instruments

New ruggedized electrical instruments, capable of withstanding severe vibration, shock, and weather condi-



tions, are made in 2.5- and 3.5-in. sizes; are hermetically sealed, and conform to Gov. spec. MIL-M-10304.—*Roller-Smith Corp., Bethlehem, Penna.*

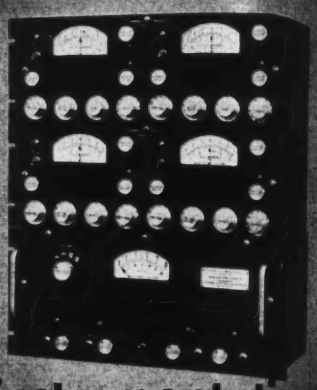
Mention No. 220 when filling out card.

Electronic-color-code Chart

New 36 x 30 inch chart, printed in 11 colors, includes all color-coding requirements of entire electronic industry—transformers, cables, leads, cable capacitors, resistors, speakers, and chasses.—*Centralab Div., Globe-Union, Inc., Milwaukee, Wis.*

Mention No. 221 when filling out card.

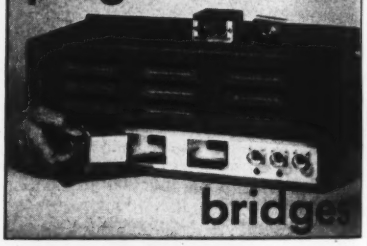
four-channel



instrumentation carrier

For low-level measurements of stress, strain, displacement, pressure, temperature, velocity, acceleration. High gain, 30 μv input for 1-ma output; bandpass frequency response, 0 to 500 cps ± 2% flat. Automatic compensation for static zero drift of oscillograph traces permits truly unattended operation. Special stress-analysis calibration network allows direct reading of stress in steel.

plug-in



bridges

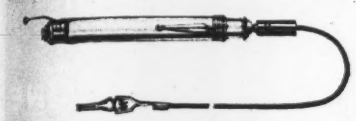
Transducer inputs feed through thermally-insulated plug-in bridge circuits for 1-, 2-, and 4-legged configurations. Facilitates summing or difference-taking within transducer arrays through single amplifier channel. Low noise and exceptional stability under local electrical disturbance, temperature and humidity variation. Send today for further data.

ELECTRONIC ENGINEERING ASSOCIATES, LTD.

1046-A Brittan Avenue
San Carlos, California

Continuity Tester

New continuity tester determines continuity of circuits and indentifies wires between terminals. Provides own power from pen-lite batteries. Uses a signal-

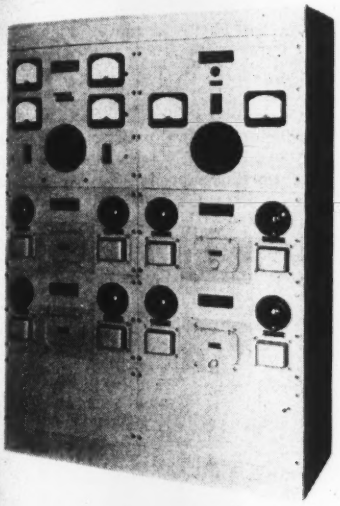


light indicator which illuminates point of contact. Requires only one hand.—*Ideal Industries, Inc.*, 1415 *Park Ave., Sycamore, Ill.*

Mention No. 222 when filling out card.

Control Panel

New line of control panels provides variable d-c. and a.c. voltages at various amperages useful for research, ex-

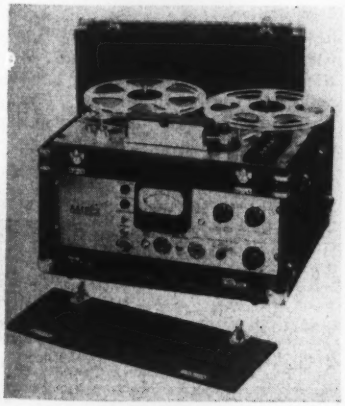


perimental, educational, and maintenance purposes. Consists essentially of self-contained units mounted in standard rack.—*Electrosig Corp., P.O. Box 113, Buffalo 21, N. Y.*

Mention No. 223 when filling out card.

Tape Recorder

New "Model 400-A" tape recorder has push-button operation. Records up to 15,000 cps. at tape speed of 7.5 or 15 ips. Available with heads for either half-



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STANDARDIZED AND STOCKED FOR PROMPT DELIVERY

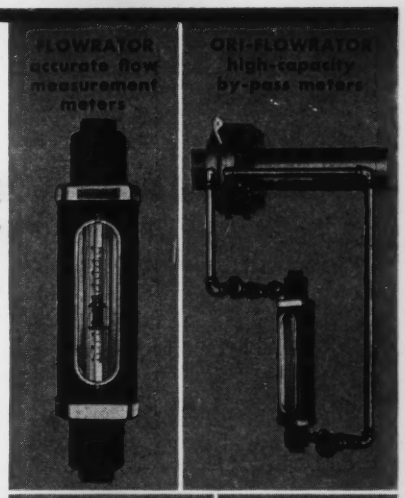
Selection of FLOWRATOR Meters and other F&P flow-rate instruments simplified

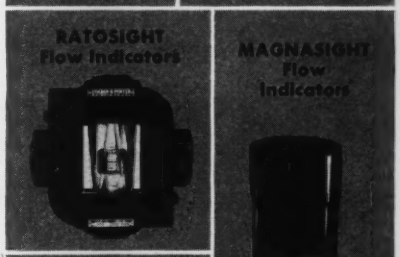
Standardization of F&P indicating instruments permits quantity manufacture, lower costs, and quicker deliveries.

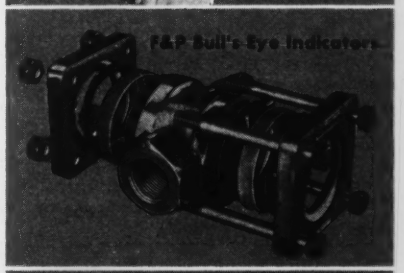
You can now select flow meters from catalog data to meet your immediate requirements. Engineering charges and manufacturing delays are eliminated.

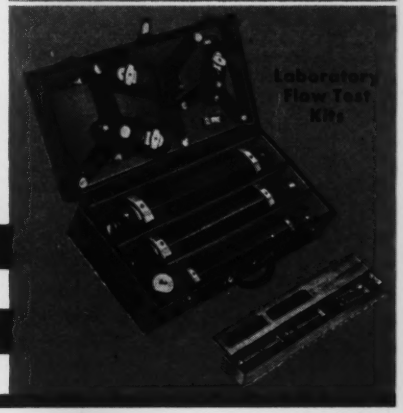
WRITE FOR NEW "STOCK FLOW METER" BULLETIN

Contains complete data, sizes, and prices with illustrations of F&P instruments now stocked. It lists all F&P sales engineering offices showing which offices carry stock meters.









FLOWRATOR

FISCHER & PORTER CO.

DEPT. 2M-5C

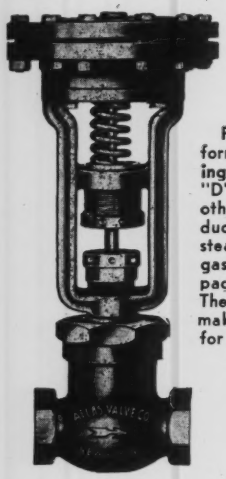
HATBORO, PENNSYLVANIA, U. S. A.

PROCESS CONTROL INSTRUMENTS

ATLAS Type "D" Reducing Valve

For pressures up to 250 pounds, Steam, Air, Oil, or Gas Service. Stainless Steel Needle Seats, Sizes ½" and ¾". Renewable Disc with Bronze or Stainless Steel Seat, ½" to 2".

Regrinding Bronze or Stainless Steel Bevel Disc with Bronze or Stainless Steel Seat, ½" to 2". Screwed Ends. Flanged Ends if desired. Diaphragm Operated. Bronze Bodies.



For complete information concerning ATLAS Type "D" as well as other Pressure Reducing Valves for steam, water, air, gas, or oil, get 52-page Bulletin 1-A. The coupon below makes it easy to ask for it.

Type "D" is well liked by all users for reduced working pressures from one pound to 150 pounds.

Type "D" valves are unusually simple as will be discovered when you study bulletin 1-A. They give accurate and close regulation. Easy to inspect. Durable. Efficient. Made by a concern that has specialized in regulating valves *exclusively* for over a half century.

ATLAS VALVE COMPANY
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292 SOUTH ST. NEWARK 5, N. J.

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☐ Without obligation, please send me the ATLAS Regulating Valve Bulletin No. 1-A. Also please send complete information on the following ATLAS products:

☐ Damper Regulators	☐ Pump Governors
☐ Temperature Regulators	☐ Oil Control Cocks
☐ Exhaust Control Systems	☐ Humidity Controllers
☐ Pressure Regulators	☐ Thermostats
☐ Campbell Boiler Feed Water Regulator	☐ Balanced Valves
	☐ Control Valves

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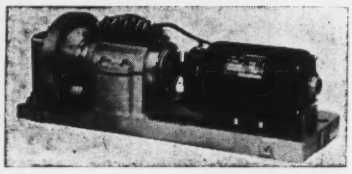
NEW INSTRUMENTS

track or full-track recording. Noise level is 55 db. below 2 percent total harmonic distortion level. Wow and flutter are less than 0.2 percent at 15 ips.—*Ampex Electric Corp., Redwood City, Calif.*

Mention No. 224 when filling out card.

Shaft-position Indicator

New "Shaft-Monitor" detects angular position of rotating shaft and gives digital representation. Consists of electromechanical locator unit coupled to reference shaft and electronic converter

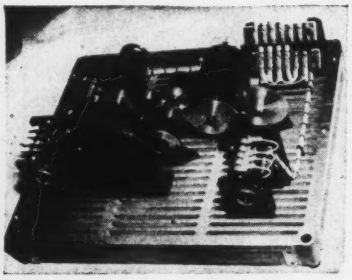


unit. Magnetic recording mechanism indicates on command (as often as twenty times per sec.) position of reference shaft. Measurements accurate to 0.09 degree can be displayed in digital form, on magnetic tape, punched tape, etc.—*Engineering Research Associates, Inc., Dept. A, 1902 W. Minnehaha Ave., St. Paul W4, Minn.*

Mention No. 225 when filling out card.

Electromechanical Breadboard

New line of electromechanical components for quick breadboarding of systems includes high-speed magnetic clutches, differentials, precision stand-



ard gears, hangers, mounting brackets for synchros, servomotors, pot-rheostats, etc.—*Instrument Components, Inc., Box 45, Hillside Manor P. O., New Hyde Park, N. Y.*

Mention No. 226 when filling out card.

Amplifier

New "Type 221-A Laboratory Amplifier" features 20-watt output; frequency response flat from 12,000 to 55,000 cps. with controlled cutoff characteristics; first-order intermodulation component less than 0.1 percent; harmonic distortion less than 0.5 percent; hum level minus 90 db. below full output; and input impedance of 0.5 megohms for low-level input, 1.5 megohms for high-level input.—*Hermon Hosmer Scott, Inc., 385 Putnam Ave., Cambridge 39, Mass.*

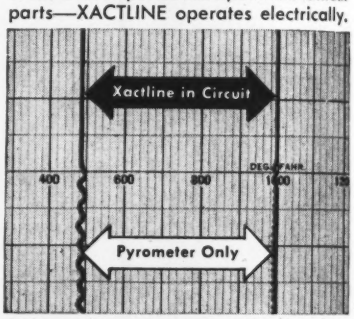
Mention No. 227 when filling out card.

Automatic "STRAIGHT-LINE" TEMPERATURE CONTROL with XACTLINE

ELIMINATE
Overshooting
Undershooting

Are you going to continue to put up with that troublesome overshooting and undershooting inherent in your conventional pyrometer control—especially when it is so easy to eliminate that saw-tooth effect?

Put XACTLINE in the control circuit. XACTLINE anticipates the temperature changes—before they occur. And too, it nullifies the varying amounts of thermal lag, residual heat, and mechanical lag—producing a short on-off cycle resulting in "Straight-Line" temperature control. This performance is possible because there is no dependence upon mechanical parts—XACTLINE operates electrically.



Exact reproduction of temperature chart for a heating process showing the comparison of the "Straight-Line" temperature control produced by XACTLINE and the saw-tooth curve obtained with only conventional control.

XACTLINE is applicable to any indicating or recording pyrometer control of the millivoltmeter or potentiometer type. It should be used wherever close temperature control is required—any type of electrically heated oven, furnace, kiln, injection molding machine, and fuel-fired furnaces equipped with motor-operated or solenoid valves.

XACTLINE is a complete unit. No adjustment or coordination with the control instrument is required regardless of the size of the furnace, length of the heating cycle, or size of the load. Installation is very simple—can be either flush or surface mounted.

PRICE $89.50 F.O.B. CHICAGO
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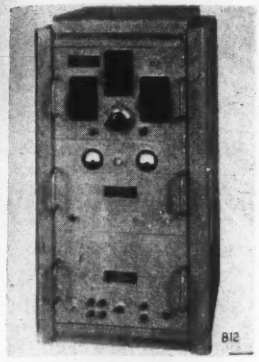
Frequency Marker Generator

New "Model FM-L" frequency marker produces calibration signals at 1-Mc, or 10-Mc. intervals within frequency range of 950 to 2040 Mc. Frequencies



can be determined to accuracy of one part in one-hundred million. Interpolation oscillator produces comparison signal by which frequency of unknown signal is determined to within 10 kc.—*Polarad Electronics Corp.*, 100 *Metropolitan Ave., Brooklyn* 11, *N. Y.*

Mention No. 228 when filling out card.

Electronic Timer

New "Type CK Models C and D" electronic timers can be started by momentary or sustained contact. Uses cold-cathode trigger tube. Separate 8-

amp. SPST normally-open contacts close at start and re-open at end of timed cycle. Ranges available are 1.5, 3, 6, or 12 sec. Dial has 100 graduations. Operates from 105-125 v. 60 cycles. Delay relay handles 8 amp. non-inductive load at 125-v. a.c. in SPDT circuit. —*Farmer Electric Co.*, 21 *Mossfield Rd., Waban* 68, *Mass.*

Mention No. 229 when filling out card.

Dielectric Sample Holder

New "Type 1690-A Dielectric Sample Holder" is micrometer holder of "Hartshorn" type for use in measurements of dielectric constant and dissipation factor on solid dielectric samples from 0.1 to 100 Mc., and at audio frequencies. Uses micrometer screw to drive movable grounded electrode; spacing is

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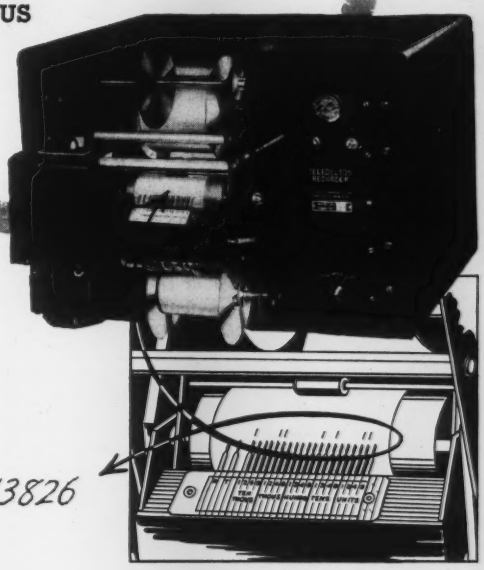
TELEDELTOS RECORDER

IMMEDIATELY VISIBLE
INSTANTANEOUS
PERMANENT
DIGITAL

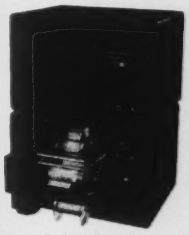


Designed to record measurements obtained on Potter Electronic counters, scalers, chronographs and frequency-time counters.

The Potter Instrument Co. High Speed Teledeltos Recorder provides a permanent recording of digital information at rates up to 150 six-digit answers per second. The measurements are transferred to electrically sensitive paper using four stylii for each digit arranged in the famous Potter (1-2-4-8) read-out. The records are indexed intermittently and controlled by the events being measured.

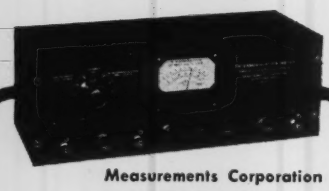
Write for information on specific applications to Dept. 4A.

POTTER RECORDING COUNTER CHRONOGRAPH



Measures time intervals up to 0.10000 second in increments of 2.5 microseconds. (Higher resolutions are also available.) Applicable to projectile velocity measurements, frequency measurements, geophysical measurements, telemetering and wherever micro-second timing is required.

POTTER INSTRUMENT COMPANY
INCORPORATED
115 CUTTER MILL ROAD GREAT NECK NEW YORK



Measurements Corporation
MODEL 31

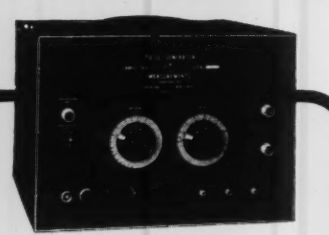
INTERMODULATION METER

- *Completely Self-Contained*
- *Direct Reading For Rapid, Accurate Measurements*

To insure peak performance from all audio systems; for correct adjustment and maintenance of AM and FM receivers and transmitters; checking linearity of film and disc recordings and reproductions; checking phonograph pickups and recording styli; adjusting bias in tape recordings, etc.

The generator section produces the mixed low and high frequency signal required for intermodulation testing. A direct-reading meter measures the input to the analyzer section and indicates the percentage of intermodulation.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY



Measurements Corporation
MODEL 79-B

PULSE GENERATOR

REPETITION RATE: 60 to 100,000 pulses per second.

PULSE WIDTH: Continuously variable from 0.5 to 40 microseconds.

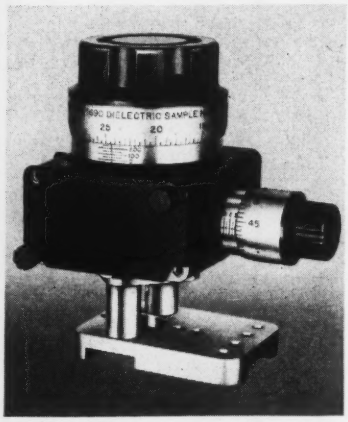
RISE TIME: Approx. 0.25 microseconds.

OUTPUT VOLTAGE: 150 volts (peak) positive.

POWER SUPPLY: 117 volts, 50/60 cycles.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

NEW INSTRUMENTS

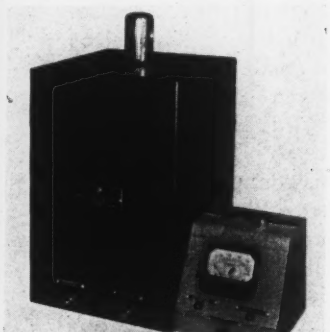


indicated in 0.1 mil. Vernier capacitor with range of 5 uuf. is provided for determining width of resonance curves in susceptance-variation method. When movable electrode comes in contact with specimen or bottom electrode, drive disengages. Specimen is shielded by sliding aluminum side panels.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 230 when filling out card.

Kilovoltmeters

New "Series 111 Kilovoltmeters" measure average d-c. voltage to 200,000 volts. Separate multiplier is immersed in non-hygroscopic wax in bakelite cylinder. Meter movement is protected against breakdown of multiplier resistor or wax, and flashover



across surface. Accuracy is 4-percent full scale. Multiplier is 21-in. high and 6 inch in diam. for 100-kv. unit, 21-in. high and 12-inch in diam. for 150-kv. unit, 40 in. high and 2-ft. in diam. for 200-kv. unit. Sensitivity of 50-kv. unit is 20,000 ohms per v.; for 150 and 200 kv. units, 10,000 ohms per v.—*Beta Electric Corp., 333 E. 103rd St., New York 29, N. Y.*

Mention No. 231 when filling out card.

Frequency Meter

New "Model FM-1A" VHF frequency meter has frequency range from 20 to 480 Mc. Frequency is read from dial. Carrier frequency can be modulated

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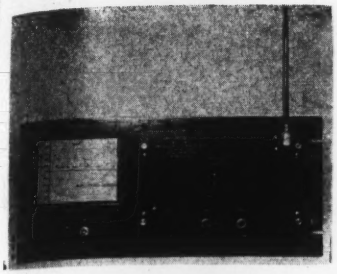
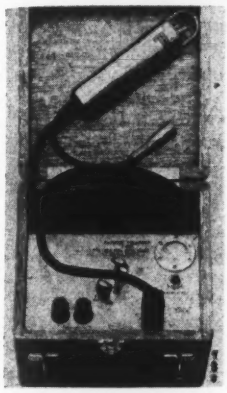


above 30 percent at 1,000 cycles. All frequency measurements are referenced to 1.0-Mc. crystal with low temperature coefficient.—*Gertsch Products, Inc., Los Angeles, Calif.*

Mention No. 232 when filling out card.

Cathode Followers

New series of cathode followers match high-impedance devices to standard electronic equipment. "Models F403 and F405" are battery powered; "F407"

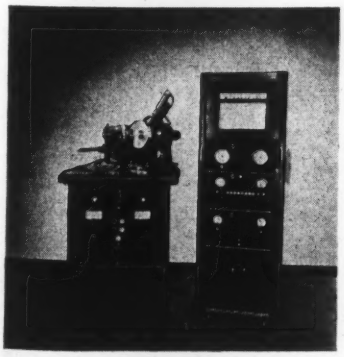


operates on 110-v. 60 cycles. "Model F407" features frequency response from 1 to 200,000 cps., input impedance of 60 megohms, output impedance of 1000 ohms, gain of 0.99, noise level under 0.5 millivolt, overloading of 60 volts.—*Gulton Mfg. Corp., Metuchen, N. J.*

Mention No. 233 when filling out card.

X-ray Diffraction Spectrometer

New recording X-ray spectrometer consists of basic X-ray diffraction unit, wide-range Geiger-counter goniometer, and electronic circuit panel with



Stuck without WARNING

Who's stuck?

Safety valves that weren't safe? The plant which installed them?

None of this was necessary. If you want 100% safety—and you'd hardly want less—there's one sure way to get it—specify BalanSeal or FarriSeal Valves.

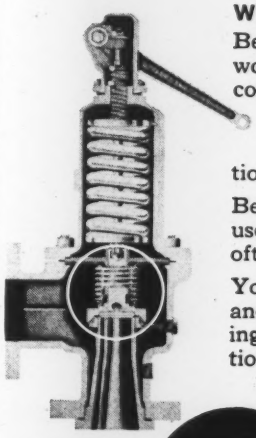
Why?

Because they *can't* stick, plug or corrode. Critical working parts are permanently isolated from any contact whatever with the lading.

Because they're unaffected by back pressures in the discharge manifold due to its own operation or to the opening of other valves in the line.

Because these features make it possible for you to use smaller discharge piping, an economy which is often substantially more than valve cost.

You'll be interested in the engineering of BalanSeal and FarriSeal Valves—design which is rapidly gaining acceptance in hundreds of successful installations.



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Internationally known development company saves time and money in solving fuel injection problems on modern aircraft engines. Special EPL PRESSUREGRAPH **simultaneously** measures and records four individual pressure-time phenomena of dynamic, static or transient pressures on the 4-beam cathode-ray oscilloscope.

Pressure impulses from four electronic pick-ups are carried to four individual pressuregraphs where timing and positioning markers from the Electro Syncro-Marker are superimposed. All four pressure impulses, with markers, are amplified and can be viewed or photographed directly for quick, accurate analyses.

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Measure dynamic or static displacement, vibration or movement of any metal body **without** physical contact.

SALES ENGINEERS IN PRINCIPAL CITIES

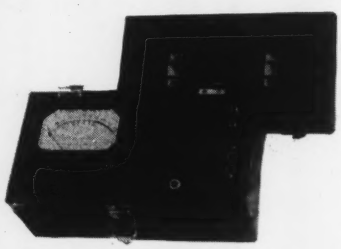
NEW INSTRUMENTS

"Brown" strip-chart recorder. Operates on 200-240 v. a.c. Goniometer is driven by synchronous motor at five speeds. Inclination of specimen face to horizontal can be varied. Electronic panel includes timer, scaling circuits, and voltage stabilizer.—*North American Philips Co., 750 S. Fulton Ave., Mt. Vernon, N. Y.*

Mention No. 234 when filling out card.

Volume Indicator

New "Series 911 Volume Level Indicator" is rugged, self-contained, and requires no batteries or external power supply. Indicating meter is a copper-

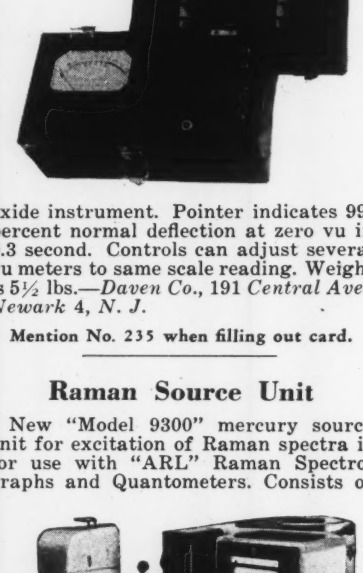


oxide instrument. Pointer indicates 99-percent normal deflection at zero vu in 0.3 second. Controls can adjust several vu meters to same scale reading. Weight is 5½ lbs.—*Daven Co., 191 Central Ave., Newark 4, N. J.*

Mention No. 235 when filling out card.

Raman Source Unit

New "Model 9300" mercury source unit for excitation of Raman spectra is for use with "ARL" Raman Spectrographs and Quantometers. Consists of



helical mercury lamp with auxiliary electrical circuits and coolant. Electrodes are cooled mercury pools.—*Applied Research Laboratories, Glendale 4, Calif.*

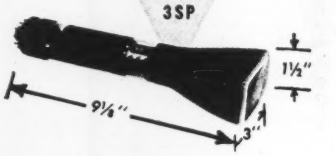
Mention No. 236 when filling out card.

Filter-paper Counting System

New "Filter Paper Counter FPC 1 and FPC 2" works interchangeably with flat-sample counting chambers on company's proportional counters. Conversion kit comes with chamber. Chamber permits use of filter papers up to 7 x 6 inches in smaller counter and 7 x 10 inches in larger counter. Offers

THE RAYONIC® CATHODE RAY TUBES

BY WATERMAN



Since the introduction of Waterman RAYONIC 3MP1 Tube for miniaturized Oscilloscopes, Waterman has developed a rectangular Tube for multi-trace oscilloscopy. Identified as the Waterman RAYONIC 3SP, it is available in P1, P2, P7 and P11 screen phosphors. The face of the Tube is 1½" x 3" and the over-all length is 9⅛". Its unique design permits two 3SP Tubes to occupy the same space as a single 3" round tube, a feature which is utilized in the S-15-A TWIN-TUBE POCKETSCOPE. On a standard 19" relay rack, it is possible to mount up to ten 3SP tubes with sufficient clearances for rack requirements. Thus 3SP RAYONIC tube is ideal for multi-trace oscilloscopic work.

Maximum 2nd anode voltage 2750 volts ... Satisfactory operation can be achieved at 600 volts ... Vertical deflection factor 52 to 70 volts DC per inch per kilovolt ... Horizontal deflection factor 73 to 99 volts DC per inch per kilovolt ... Grid cut-off voltage 2.8 to 6.7% of 2nd anode potential ... Focusing voltage 16.5 to 31% of 2nd anode voltage ... Heater 6.3V at .6 amp ... Twelve pin small shell duodecal base ... Tube can be mounted in any position ... 3SP1 JAN approved.

WATERMAN PRODUCTS CO., INC.

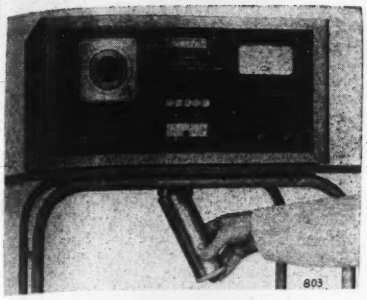
PHILADELPHIA 25, PA.
CABLE ADDRESS: POKETSCOPE

WATERMAN PRODUCTS INCLUDE:

3JP1 & 3JP7 JAN RAYONIC CR TUBES
3JP2 & 3JP11 RAYONIC CR TUBES
3MP7 & 3MP11 RAYONIC CR TUBES
3RP1, 2, 7, 11 RAYONIC CR TUBES

Also POCKETSCOPES, PULSESCOPES, RAKSCOPES and other equipment

WATERMAN PRODUCTS

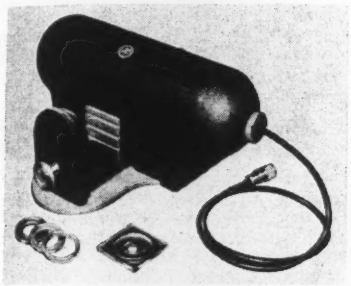


full sensitivity to alpha and beta radiation of all energies and yields essentially 2-pi geometry, less absorption, plus back-scattering.—*Nuclear Measurements Corp., Indianapolis* 18, *Ind.*

Mention No. 237 when filling out card.

Horizontal Iron Shield

New "Model 3030A Shield" is arranged for mounting of glass geiger tube horizontally, and placement of a sample close to this tube surrounded by 2½ in.

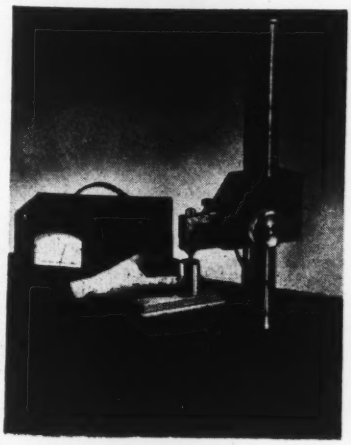


of iron for background shielding purposes. Shield accepts many sizes of sample holders, and incorporates means of counting in three accurately predetermined geometries. Absorbers can be used when desired.—*Nuclear Instrument & Chemical Corp.*, 229 *W. Erie St., Chicago, Ill.*

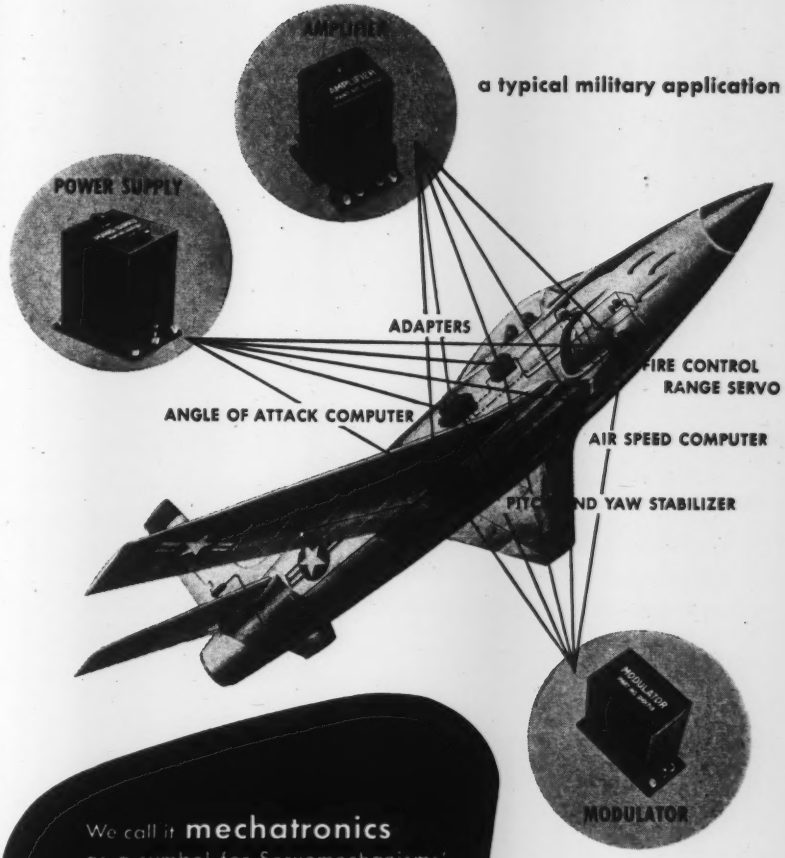
Mention No. 238 when filling out card.

Electronic Gage

New "Par-Ac" production gage consists of induction-type gage head mounted on stand and high-stability 4-tube amplifier which reads 0.0005 and 0.00005 in., or 0.0001 and 0.00001 in. per scale div. Response is rapid and



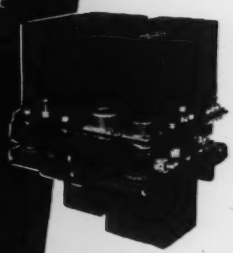
mechatronics*



We call it **mechatronics** as a symbol for Servomechanisms', Inc., ***technique*** for the multiple and interchangeable use of standard, functionally packaged, servo components in varied electronic and electro mechanical systems.

Mechatronics fulfills the urgent need for:

- Spatial Adaptability
- Instant Maintainability
- Training Simplicity
- Ease of Assembly



A typical Servomechanisms, Inc., assembly using packaged functions.

SERVOmechaNISMS INC.

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Burlington

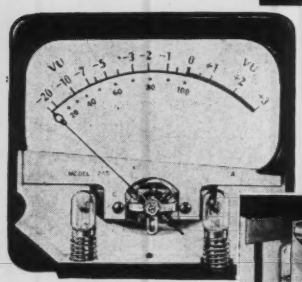
ILLUMINATED INSTRUMENTS

EXCELLENT LIGHT DISTRIBUTION affords EASE IN READING. GLARE REDUCED to a minimum by retaining COMPACT DESIGN of front case extension.

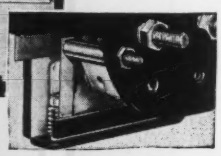
REFLECTED LIGHT PRINCIPLE permits use of standard METAL DIALS eliminating translucent materials that discolor with age and use.

BULB REPLACEMENT FACILITATED by removal of single lamp assembly.

Two 3.8 volt STANDARD BULBS are used and connected in series.



Available in all ranges 3½" and 4¼" rectangular semi-flush models.



Cutaway views showing positions and connections of lamp assembly.

Write Dept., H-22 for complete details.

BURLINGTON INSTRUMENT COMPANY
BURLINGTON, IOWA

Engrave ... PANELS UP TO 25" WIDE IN YOUR OWN SHOP WITH THE NEW ENGRAVOGRAPH Portable Model 1-S

TRACER GUIDED FOR UNSKILLED LABOR

Send for Booklets
I-S-37 portable model
H-37 heavy duty model

The *only* portable machine which reproduces *15* sizes from one master alphabet.

The *only* one with *adjustable* copy holding slides for multiline engraving in one set-up.

Self-centering holding vise for nameplates.

NEW HERMES, Inc.
13-19 University Place New York 3, N.Y.

THIS FEATHERWEIGHT WILL

LICK SOLDERING FATIGUE!

THE NEW
HEXACON
BANTAM
MODEL 30H

Weight—5½ Ounces • Watts—40 or 60 • Tip Dia.—Both 1/8" and 1/4" Tips Furnished with Each Iron • Price— $5.50

So light its weight is hardly noticeable. Outperforms any iron of equal size. Hatchet design makes it more comfortable and practical to use than a pencil iron. No transformer required. Write for complete catalog.

HEXACON

HEXACON ELECTRIC CO.
179 WEST CLAY AVE., ROSELLE PARK, N. J.

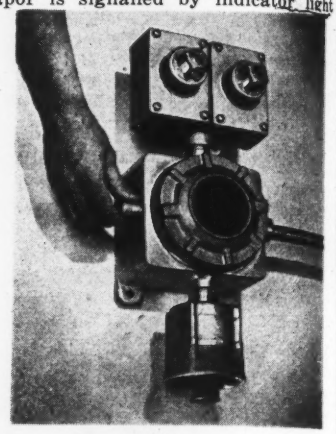
NEW INSTRUMENTS

without overshoot. Gage head accomodates work of any height to 8 3/8 in. above anvil.—*Graham-Mintel Instrument Co., 735 Carnegie Ave., Cleveland 15, Ohio.*

Mention No. 239 when filling out card.

Combustible-gas Alarm

New "Model EE Combustible-gas Alarm" is explosion-proof. Sensing unit in bell-shaped housing is weather-proof. Vapor is signalled by indicator light

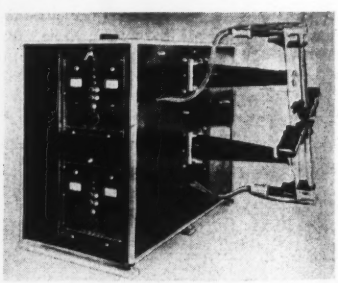


and alarm units. Either self-reset or lock-in arrangements can be provided. Unit is a-c. operated and designed for rough service. Electronic trigger-tube circuit is arranged for easy removal.—*Johnson-Williams, Ltd., 2613 Third St., Palo Alto, Calif.*

Mention No. 240 when filling out card.

Tin-plate Gage

New tin-plate thickness gage uses X-ray beam which penetrates tin and strikes underlying steel. Rays emitted by iron are measured by Geiger counters. Two Geiger counter tubes are

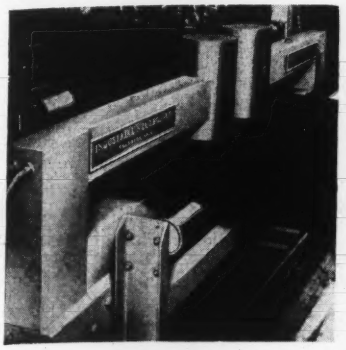


mounted on same side of tin plate as X-ray tube. X-ray generator operates on 200-240 v. a.c. Total count may be read from electromechanical register or tape-printing register. Counts are converted to thickness by calibration curve. Handles tin coatings from 0 to 150 micro-inches. Available as single or double unit for one or both sides of steel plate.—*North American Philips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y.*

Mention No. 241 when filling out card.

Beta-ray Gage

New "AccuRay Model R" radiation gage provides readings in square yard weight (with accuracy of 1 percent) of sheet material. Positioning control pro-



vides profile readings. Remote control station has repeat meter. Beta-radiation source is below sheet; detector above sheet measures radiation that penetrates sheet. Never requires recalibration.—*Industrial Nucleonics Corp.*, 1205 *Chesapeake Ave., Columbus* 12, *Ohio.*

Mention No. 242 when filling out card.

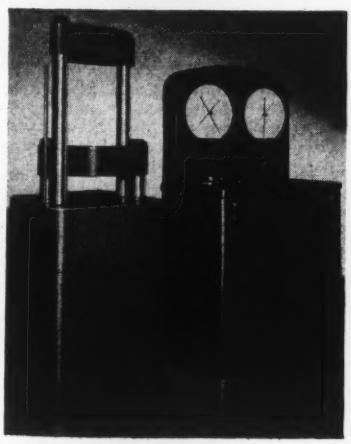
Wall-thickness Gage

New electronic gage measures wall thicknesses of straight or tapered tubing up to six feet in length. Consists of two horizontal arms on base. Contact points on arms connect to electronic control box. Two readings of vernier are taken, one with tubing in place, second with it removed and vernier touching lower contact point. Difference in readings is wall thickness to 0.001 in. —*Fairchild Engine & Airplane Corp., Hagerstown, Md.*

Mention No. 243 when filling out card.

Universal Testing Machine

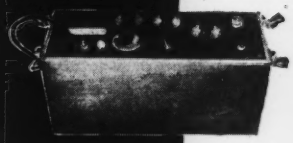
New "Model 120-H" low-cost universal testing machine has 120,000-lb. capacity. Hydraulic loading unit is separate from indicating and control unit. Load (either tension or compression) is applied by integrated piston and elevating cage consisting of table, two uprights, and upper gripping head, which



Edin instruments

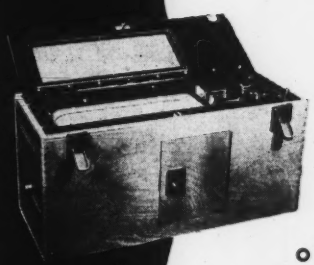
OSCILLOGRAPH GALVANOMETER

No's. 8001, 8002, 8003 and 8004 ink-writing galvanometers have sensitivities from 3.5 to 40 volts per cm., resonant frequencies from 15 to 120 cps., resistances from 1000 to 2000 ohms, frequency response up to 350 cps., and a single-jewel pivot construction. Units are designed for multiple operation up to 10 channels in a total width of 12 inches.



DIRECT-COUPLED AMPLIFIER

No. 8100 direct coupled amplifier has a voltage amplification of 13,000 with a maximum output of 70 volts. Frequency response from d.c. to 10,000 cps. is flat within 10%. Input impedance is 2 megohms; output impedance is 150 ohms. Input may range from 0.1 mv. to 100 volts. Stability is better than 0.1 mv. per thirty minutes, or 0.5 mv. per day. Attenuator is stepped for factors from 1 to 1000.



OSCILLOGRAPHS

Recorders can be supplied with 1, 3 or 9 chart speeds ranging from 0.1 mm./sec. to 250 mm./sec. See specifications of OSCILLOGRAPH GALVANOMETER for frequency range.

OSCILLOGRAPH AMPLIFIER

No. 8121 special amplifier has a time constant of 1 second, an exponential response to a square wave at high gain, input impedance of 1 megohm, and input form 0.1 mv. to 1000 volts. At low gain, No. 8121 becomes a DC amplifier with a voltage gain of 100 and an input of 10 mv./mm.

HIGH-GAIN AMPLIFIER

No. 8130 amplifier has a voltage gain of 1,000,000 and includes a built-in pre-amplifier. Frequency response is from 1 to 200 cps. Input may range from 10 microvolts to 100 millivolts. This amplifier is particularly suited for Biological studies.

Many other types of recording and amplifier circuits are available and special equipment can be assembled to meet particular specifications.

EDIN COMPANY, INC.
207 Main Street
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Please send complete information on:

☐ RECORDERS
☐ NO. 8121 AMPLIFIER
☐ GALVANOMETERS
☐ No. 8100 AMPLIFIER
☐ No. 8130 AMPLIFIER
☐ ..... SPECIAL (Enclose details)

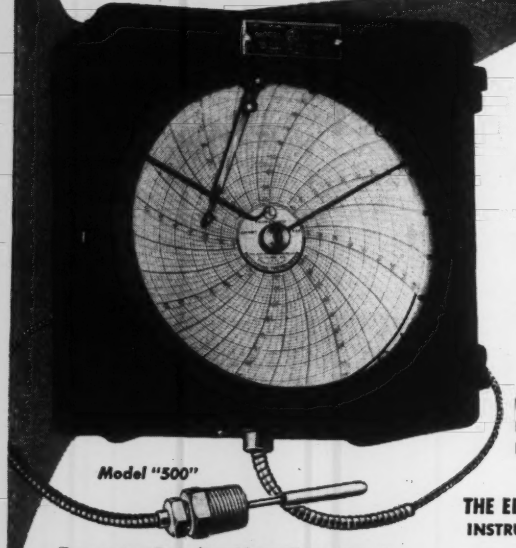
..... (NAME)

..... (NO.) (STREET)

..... (CITY) (STATE)

..... COMPANY POSITION

AUTO-LITE



...for TEMPERATURE RECORDING

★ This low-cost protection gives permanent proof of temperature behavior.

★ Various standard chart ranges from minus 40°F. to plus 550°F.

★ 3 standard types; choice of 24-hr. or 7-day cycle.

Send for new catalog G-143-B, describing many styles of Auto-Lite temperature indicators and recorders.

Temperature Recorder with capillary tubing for EYE-LEVEL reading. Priced from $42.50.

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INSTRUMENT AND GAUGE DIVISION
TOLEDO 1, OHIO
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TEMPERATURE RECORDERS & INDICATORS

The *Accurate* Way to Measure Extreme Temperatures *at a glance*

The Simplified PYRO Optical Pyrometer

SELF-CONTAINED. No correction charts, no accessories, no up-keep. *Direct-reading.*

ACCURATE. Permits *close* and *rapid* temp. determination — even on *minute spots, fast-moving objects, smallest streams.* ("Special Foundry Type" and "Triple Range" also have RED Correction Scale for determining *true spout* and *pouring* temps. of molten iron, steel in the open.)

LIGHT IN WEIGHT—Only 3 lbs. complete. Handy.

PROVED IN USE—Thousands in daily use.

Stock Ranges 1400°F. to 7500°F.

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Specify... GM

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GALVANOMETERS AND MOVEMENTS...

Ideal as a built-in component of other instruments—with the sensitivity and ruggedness that is especially desirable for Colorimetry, Densitometry, and various other measurements. Unit includes mirror movement, magnet and zero correction knob. Choice of 4 standard models.

Write us about your application and requirements

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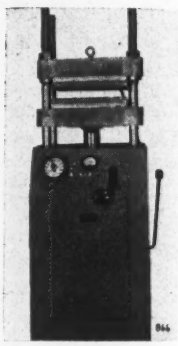
NEW INSTRUMENTS

have 6-inch power stroke. Loading speed is between 0 and 2 in. per min. Load indication is function of hydraulic pressure in loading cylinder. Indicator dial has 16-in. dia.—*Baldwin-Lima-Hamilton Corp., Phila. 42, Penna.*

Mention No. 244 when filling out card.

Hydraulic Laboratory Presses

New 50-ton series of presses are automatic. "Model 50-15M" has 12 x 15 in. platens. "Model 50-24M" has 18 x 24 in. platens. Platens are closed rapidly by



high-speed hydraulic pump. Hydraulic mechanism with 7 in. stroke provides total force of 100,000 pounds. Available for either 115-v. or 230-v. a-c. operation. Weight is 1550 and 1950 pounds.—*Hydraulics Div., Wabash Metal Products Co., P.O. Box 305, Wabash, Ind.*

Mention No. 245 when filling out card.

Abrasion Tester

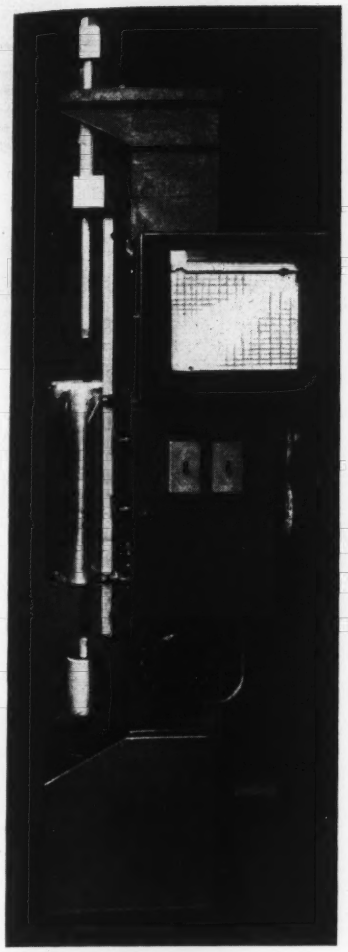
New "Abraser" has dual abrading wheels which rub specimen in two directions and traverse 360-degree circle. Provides 3 standard pressures against

specimen—250, 500, and 1000 grams. Variety of holders for painted and plated surfaces, plastics, fabrics, etc.—*Taber Instrument Corp., 111-ST Goundry St., N. Tonawanda, N. Y.*

Mention No. 246 when filling out card.

Creep Recorders

New recorders are for "Baldwin" lever-type creep machines and 4000-lb. creep-relaxation testing machine. Creep specimen deformation of 0.020 in. produces full-scale pen movement of 10 in. across strip chart driven at ¼ in. per hr. by synchronous motor. A 150-ft. chart roll gives 7200-hr. record (300 days). Creep is amplified



and transmitted from extensometer by synchro motor; pen carriage is driven by servo motor through flexible shaft and gear reducer.

For creep-relaxation records, lowering of stress in specimen is recorded by conventional "Microformer" servo-system operated as extensometer on spring-block loading device through which constant strain is maintained. Receiving "Microformer" moves pen across 10-inch strip chart.—*Baldwin-Lima-Hamilton Corp., Philadelphia 42, Penna.*

Mention No. 247 when filling out card.

Film-footage Indicator

New mechanical unit indicates film footage in "Mitchell" magazines. Serves either 35- or 70-mm. film; models available for both 400- and

An Isotronic First*

±0.01% AC REGULATION!

That's the degree of accuracy attained by Sorensen's new Model 1001 AC Line Voltage Regulator!

Heretofore, the closest regulation in commercially available regulators has been ±0.1%, regardless of manufacturer or circuit approach. Now, Sorensen's continuing study and design refinements have produced a super-accurate regulator — the model 1001 — as a *standard* catalog item.

GENERAL SPECIFICATIONS

Load range	0 — 1000 VA
Input voltage range	95 — 130 VAC, 1φ, 55 — 65~
Load P. F. range	0.7 lagging to 0.95 leading
Output voltage	115 VAC, 1φ (adjustable from 110-120 volts)
Distortion	3% max.
Time constant	0.1 seconds
Regulation accuracy	±0.01%

The accuracy is *guaranteed* at room temperature, for a resistive load, an input variation of ±10%, and over a two-to-one load change. For *all* other conditions within the specifications, the Model 1001 has a proportionate amount of accommodation.

Model 1001

Note these extra features

- **Combination twist-lock and double-T receptacle, or, output terminals to eliminate contact resistance.**
- **Three-function output switch for**
  1. **Normal regulator functioning.**
  2. **Operation with integral semi-fixed resistance in place of potentiometer.**
  3. **Direct load connection with the control diode for regulation of voltages other than 115 volts.**
- **Only FOUR vacuum tubes and NO relays are used.**
- **All tube filament voltages are regulated for long dependable life.**

WRITE FOR FULL INFORMATION

*Isotronics is a trade marked word pertaining to the electronic regulation and control of voltage, current, power, or frequency.

FOR THE LATEST AND BEST IN ISOTRONICS:

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DeJUR

1½" Panel INSTRUMENTS

Precision built DeJUR 1½" instruments for applications where space must be conserved. DeJUR rugged construction. Both models in all ranges and sensitivities. External shunts and multipliers available for various ranges. Complete magnetic shielding and methods of lighting scales. Built to government specifications.

DeJUR MODEL 130

Aluminum Case
One Hole Ring Mounting

- DC VOLTMETERS
- AMMETERS
- MILLIVOLT METERS
- MILLIAMMETERS
- AC RECTIFIER TYPES (self-contained).

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De JUR MODEL 112

Also available • 2½" • 3½" • 4" panel meters in all standard ranges. MIL-M-6A and A. S. A.

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MANUFACTURERS OF SCIENTIFIC PRECISION EQUIPMENT FOR OVER A QUARTER OF A CENTURY
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ELECTRONICALLY REGULATED
LABORATORY POWER SUPPLIES

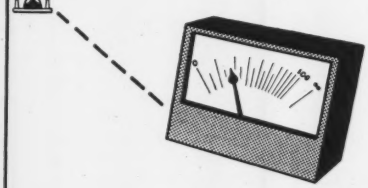
BENCH MODEL 25

- **INPUT:** 105 to 125 VAC. 50-60 cy
- **OUTPUT #1:** 200 to 325 Volts DC at 100 ma regulated
- **OUTPUT #2:** 6.3 Volts AC CT at 3A unregulated
- **RIPPLE OUTPUT:** Less than 10 millivolts rms

For complete information write for Bulletin N-5

LAMBDA ELECTRONICS CORPORATION

R C INTERVALOMETER



intervals

MEASURED PRECISELY!!

0.5μ SEC.
TO
0.1 SEC.

NELSON & STREET
P.O. BOX 4342 TAKOMA PARK
WASHINGTON 12, D.C.

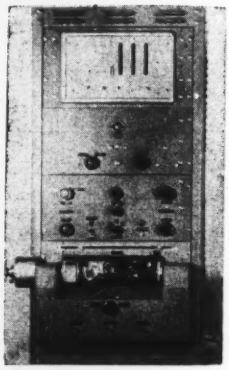
NEW INSTRUMENTS

1000-ft. magazines. Capable of interpolation to about 10 feet. Has aluminum casting, Nylon follower rolls, and requires no lubrication.—*Beckman Whitley, Inc.* 930 *San Carlos Ave., San Carlos, Calif.*

Mention No. 248 when filling out card.

Optical Density Analyzer

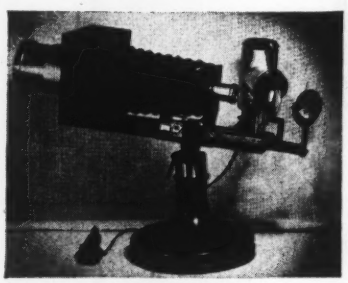
New "Type ODA-1 Optical Density Analyzer" automatically computes and displays densities of photographic print areas. Principle is quantitative geometric analysis in terms of reflected optical density. Any photographic print may be mounted on scanner drum. Range of densities can be selected. Ten runs result in complete analysis. Electronic counter counts signals from analyzer unit.—*Hogan Laboratories,* 155 *Perry St., New York* 14, *N. Y.*



Mention No. 249 when filling out card.

Diamond Magnascope

New "Model C Diamond Magnascope" makes enlarged authentic color pictures of diamonds in minute. Picture is "finger print" or permanent record of diamond.—*H. P. Zeininger Co.,* 387 *Washington St., Boston* 8, *Mass.*



Mention No. 250 when filling out card.

Optical Instruments for Tooling

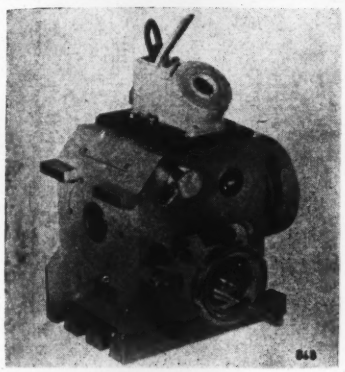
New alignment telescope with built-in autocollimating feature has 60x magnification, resolution of 2-sec. arc, and integral micrometers. Designed as universal basic tool for checking tooling, setups for large jigs, fixtures, and sub-

assemblies used in aircraft manufacture. Auxiliary optical square establishes optical plane at right angles to line of sight.—*Farrand Optical Co., Inc., Bronx Blvd., and E.* 280 *St., New York* 70, *N. Y.*

Mention No. 251 when filling out card.

Optical Dividing Head

New optical dividing head with fixed base checks angular dimensions, measures eccentricity and contours of cams, and positions machine tools by align-

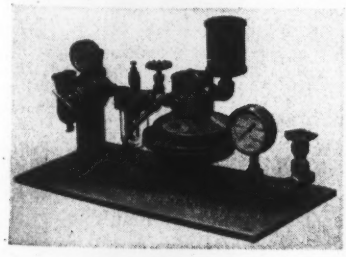


ment of scales. Readings can be made within 0.0005 in. on periphery of 12-in. circle. Optical system consists of circular dial with 30-sec. divisions and illuminated glass scale with degree marks projected onto ground-glass screen.—*F. T. Griswold Mfg. Co.,* 305 *W. Lancaster Ave., Wayne, Penna.*

Mention No. 252 when filling out card.

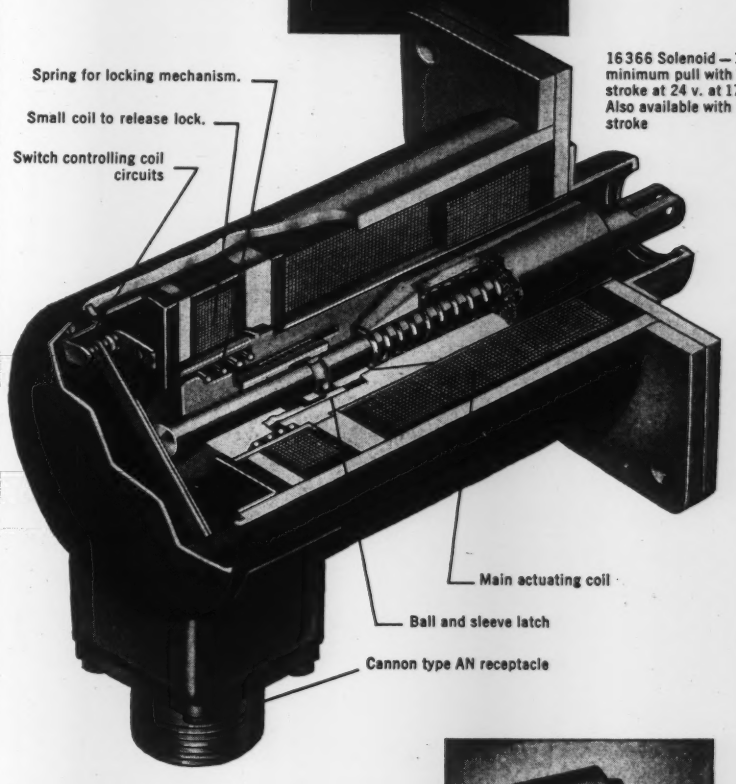
Hydraulic Power Supply

New "Model S-440" hydraulic power package has low-volume high-pressure output for hydrostatic testing. Includes air-operated pump, muffler, filter, lubricator, regulator, valves and gages. Weighs 45 lbs. Pump uses either oil or water as testing medium. Furnished



Here's why those in the know

—demand **CANNON SOLENOIDS**


Spring for locking mechanism.
Small coil to release lock.
Switch controlling coil circuits
16366 Solenoid—18.7 lb. minimum pull with 1/2" stroke at 24 v. at 170°F. Also available with 1-1/6" stroke
Main actuating coil
Ball and sleeve latch
Cannon type AN receptacle

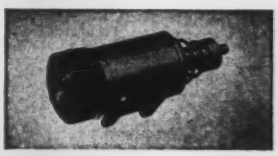
Here's a special purpose Cannon D.C. Solenoid, #16366 for aircraft. Design and safety conditions require that the armature lock in the actuated position for an indefinite time, without relying on a continuous flow of current.

The ingenious ball-and-sleeve latch locks the armature as the main coil circuit is broken through the built-in switch. When current is applied to the smaller coil, motion of the sleeve releases the main armature. Study of the drawing shows how a smooth-acting, positive lock is accomplished.

This is one of more than 60 different Cannon D.C. Solenoids built around 18 basic coils for either continuous or intermittent service. Write for Solenoid Bulletin free on request.

#1154 an intermittent service solenoid, 12v, D.C.—10.5 amps.—stroke 9/32", weight 13 oz.

#4440 a continuous service solenoid, 24v, D.C.—3.6 amp. (starting) .42 amp. (holding)—stroke 3/8" weight 16 oz.



11790 a continuous service solenoid, 24v, D.C.—3.6 amp. (starting) .42 amp. (holding)—stroke 3/8" weight 15.5 oz.

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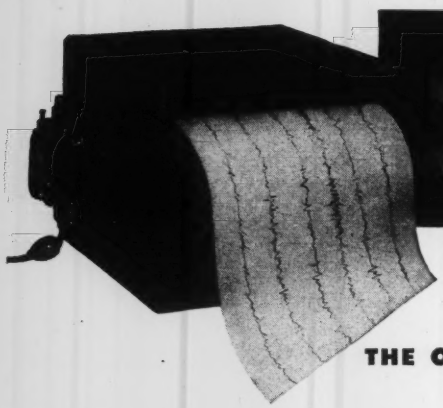

drift-free d.c. recording

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Here's a direct writing, high speed oscillograph with microvolt d-c sensitivity—made completely drift-free through an exclusive chopper type amplifier. Now you can obtain a precise record of transient variables—some formerly recorded only by photographic means—at about 100 times the speed of other recorders with comparable sensitivity.

Remember—only the Offner Dynograph gives you all of these features:

Pen Deflection Linearity of 1% with pen response of 1/120th second.

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True differential input obtained through special transformer coupling.

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Write for Illustrated Bulletin No. 152

INSTRUMENTS, INC.

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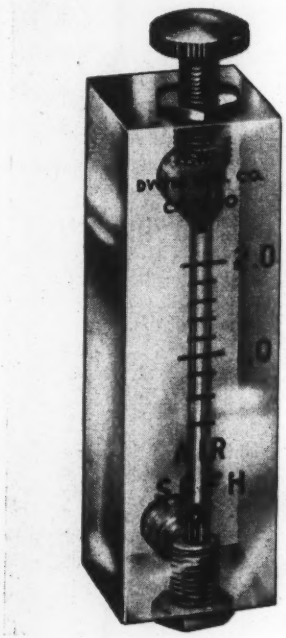
NEW INSTRUMENTS

in six standard models with ratios from 35:1 to 300:1, and with output range from 3,500 to 30,000 psi.—*Sprague Engineering & Sales Corp., Gardena, Calif.*

Mention No. 253 when filling out card.

Flowmeters

New precision flowmeters of solid acrylic construction have built-in control valve. Standard scale ranges are 0-2 to 0-10 CFH. Available with front-

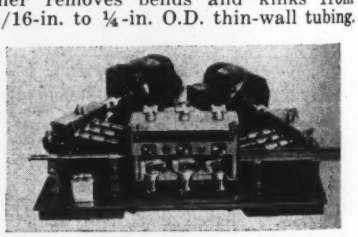


of-board or flush panel mounting for liquids or gases.—*F. W. Dwyer Mfg. Co., 317 S. Western Ave., Chicago 12, Ill.*

Mention No. 254 when filling out card.

Tubing Straightener

New "Model AYZ" rotary straightener removes bends and kinks from 1/16-in. to ¼-in. O.D. thin-wall tubing.

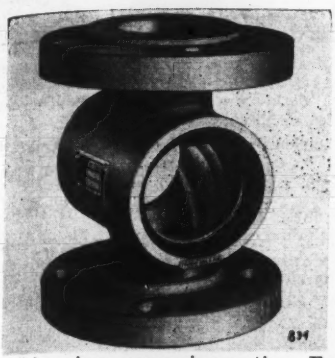


Three sets of twin cross rolls are power driven by two 1/6-hp. motors. Operating speed is 100 ft. per minute. Dimensions are 22 x 19 x 8 inches.—*Mackintosh-Hemphill Co., 901 Bingham St., Pittsburgh 3, Penna.*

Mention No. 255 when filling out card.

Sight-Flow Indicator

New "Trin-Vue" sight-flow indicator for checking flow of fluid has two windows on opposite sides. Windows are sealed by O-ring gaskets and "Truarc"

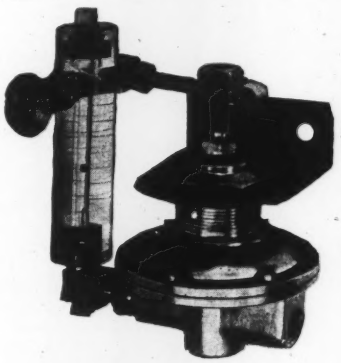


retaining rings, a new innovation. Features include positive seal, light weight, and welded design. Pressure or vacuum do not cause leaks. Available in special materials. Sizes are from ½ to 4 in. Windows are Pyrex (standard) or Herculite or Quartz (order).—*Trinity Equipment Corp., 472 Westfield Ave., East, Roselle Pk., N. J.*

Mention No. 256 when filling out card.

Flow Controller

New assembly of "Brooks Mite Purge Meter" and "Conoflow H-11 Constant-differential Relay" controls liquid or gas flows regardless of variations in

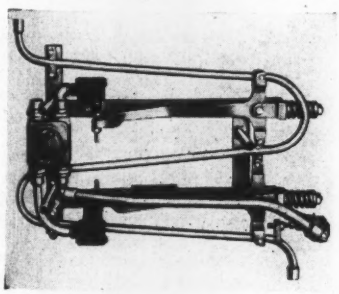


upstream or downstream pressure. Available in ranges of 0.01 to 54 gal./hr. of water and 0.2 to 216 cubic feet per hr. of air. Float indicates flow rate.—*Brooks Rotameter Co., Box 432, Dept. Y, Lansdale, Penna.*

Mention No. 257 when filling out card.

Water-level Alarm

New "Hi-Lo Water Alarm" for high-pressure service works on thermostatic principle. Signal is horn and lights. Installed without special supports or



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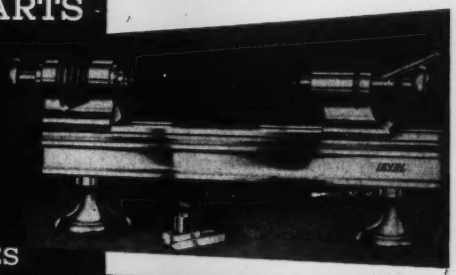

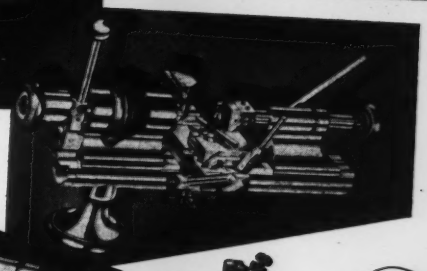

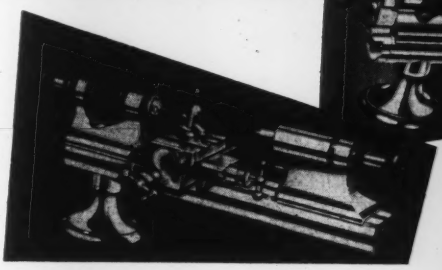

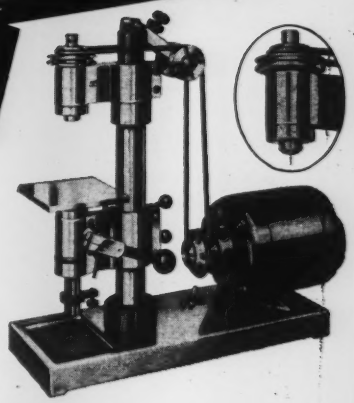

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Write for Bulletin 2B 1-H

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Pittsburgh 12, Penna.

Please send, with my compliments, a copy of the February 1952 issue of *Instruments*, to my friend(s) listed below:

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Address .....
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Company .....

2. Name .....
Address .....
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My name and address is (*Signed*)

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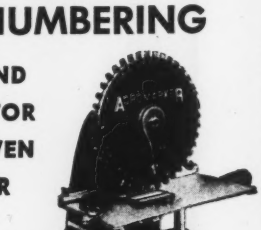

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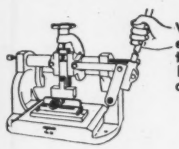

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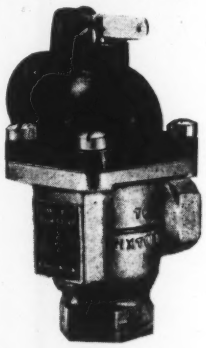
NEW INSTRUMENTS

complicated piping, with or without a water column.—*Northern Equipment Div., Continental Foundry & Machine Co., Erie 2, Penna.*

Mention No. 258 when filling out card.

Temperature Relief Valve

New "No. 201" temperature relief valve prevents excessive temperatures in hot-water tanks. Rated by AGA for heat input up to 1,200,000 Btu./hr.

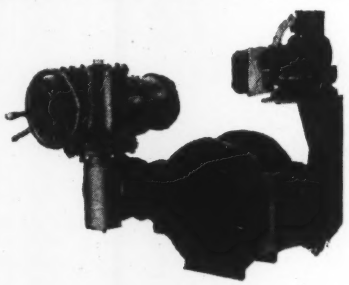


Uses "Vernatherm" thermostatic element containing mixture of organic and metallic particles, which expand and contract with temperature. Valve starts to open at 188 deg. F.; reseats automatically. Valve disk utilizes new GE Silicone rubber. Operating pressures are up to 125 lbs. Connections for inlet, drain, and flow are 3/4-inch tappings.—*McDonnell & Miller, Inc.*, 3500 *N. Spaulding Ave., Chicago* 18, *Ill.*

Mention No. 259 when filling out card.

Dual Valve

New "No 818" 125-lb. cast-iron valve consists of 12-in. beveled vane which seats against body side wall, with 4-in. vane mounted in center of larger vane.



Both vanes are motor operated. Valve has 18-8 shafts and bronze bushings. Available in various combinations.—*R-S Products Corp.*, 4600 *Germantown Ave., Phila.* 44, *Penna.*

Mention No. 260 when filling out card.

Instrument Mercury

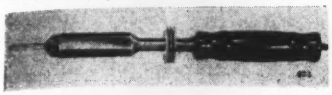
New unbreakable 5-lb. polyethylene bottle with flexible dispensing tip delivers instrument mercury directly from dust-proof chamber in which it has been purified of all contaminations. Transfer containers and exposure to impurities

are eliminated. Mercury remains bright indefinitely in storage and in instruments. Obtainable in larger containers. —*Bethlehem Apparatus Co., Inc., Hellertown, Penna.*

Mention No. 261 when filling out card.

Fast-soldering Irons

New "Model P-154" is high-speed soldering iron with plug tip. Rated at 150 watts, ¼-in. tip reaches soldering temperature above that of conventional

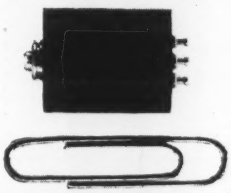


soldering irons. Special provisions in element withstand unusually high temperature developed.—*Hexacon Electric Co., 179 W. Clay Ave., Roselle Park, N. J.*

Mention No. 262 when filling out card.

Subminiature Pot

New "Model SR Potentiometer-rheostat" is subminiature, wire-wound pot. Case measures only 5/8 inch in diameter and 3/4 inch in length. Can be supplied with shaft extensions. Terminals can be wire or lug type. Resistance range is 100 to 50,000 ohms; power rating is 0.25 to 1.5 watts; resistance tolerance is ± 5 percent (± 1 percent on order); linearity tolerance is ±1 percent (±0.2 percent on order).—*Standard Electronics Mfg. Co., 8617 W. 3rd, Los Angeles 48, Calif.*



Mention No. 263 when filling out card.

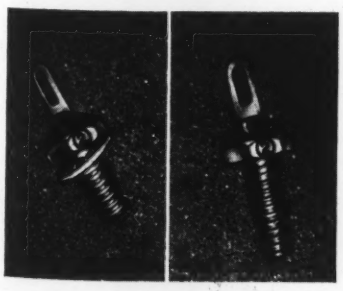
Test Leads

New "No. 329" test leads have 8-in. handles of hard rubber. Leads are kinkless, 48-in. long, have standard phone tips on ends.—*Insuline Corp. of America, 3602 35th Ave., Long Island City 1, N. Y.*

Mention No. 264 when filling out card.

Button Capacitors

New series of button ceramic capacitors for VHF and UHF applications has tiny disk capacitor element in head of threaded fastener. Features include



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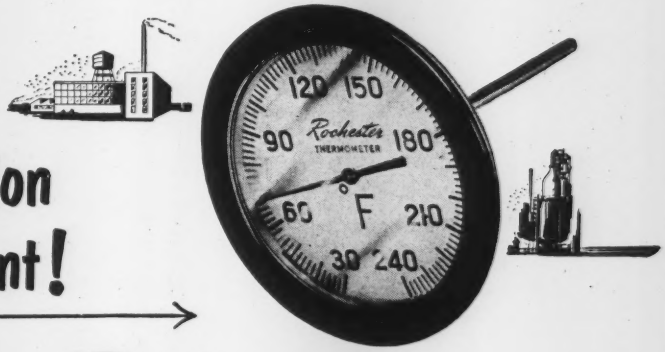

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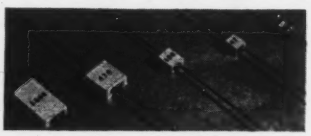
minimum ground inductance and thorough shielding. Rated at 500 v. d-c. up to 1,000 uuf. Four thread variations are available in 6-32 and 10-32 threads, self-tapping or standard.—*Sprague Electric Co., North Adams, Mass.*

Mention No. 265 when filling out card.

Capacitor

New "Type 49" capacitor has length of 0.4 in. Available up to 51 uuf. at



500 volts and to 110 uuf. at 250 volts, working. Porcelain forms dielectric and also insulates structure.—*Vitramon, Inc., Stepney, Conn.*

Mention No. 266 when filling out card.

Ceramic Capacitor

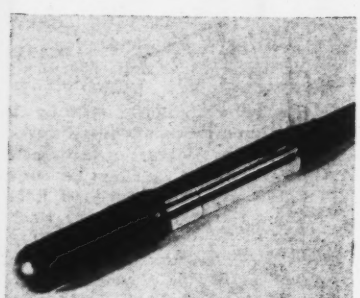
New "J-Cap" thin disk 0.005-uf. ceramic capacitor of unusual physical strength is only 0.156-in. thick and 0.594-in. dia. Working voltage is 500

v.; leakage resistance is over 7500 megohms; power factor is less than 2.5 percent.—*Jeffers Electronics, Inc., DuBois, Penna.*

Mention No. 267 when filling out card.

Pressure Transducer

New "Model BC-1" pressure transducer can be used underground or underwater. Barium titanate cylinder is hermetically sealed and covered with



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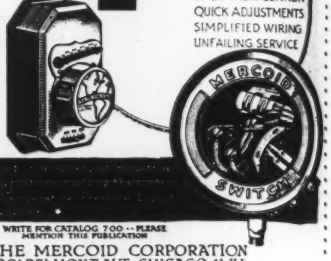

WRITE FOR CATALOG 700 ·· PLEASE MENTION THIS PUBLICATION
THE MERCOID CORPORATION
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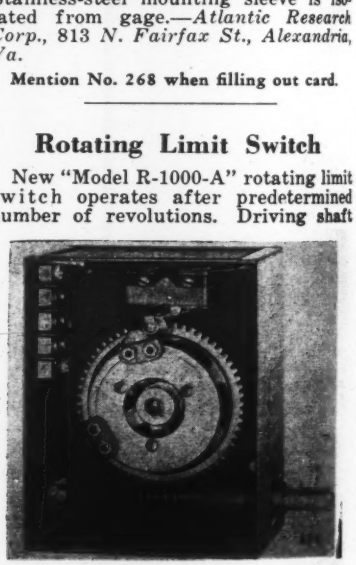
tough Neoprene sheath. Input resistances is above 1000 megohms. Response is flat from 0.5 cps. to 40 kcps. Graphite-coated coax cable minimizes spurious cable noise. Sensitivity is 1500 micromicrocoulombs/psi., or 0.15 v./psi. Stainless-steel mounting sleeve is isolated from gage.—*Atlantic Research Corp., 813 N. Fairfax St., Alexandria, Va.*

Mention No. 268 when filling out card.

Rotating Limit Switch

New "Model R-1000-A" rotating limit switch operates after predetermined number of revolutions. Driving shaft



can be placed on right or left side of case. Worm-gear combination has 60-1 ratio. Adjustable limit cams follow contour of roller.—*Crane Electric Co., 1437 W. Lake St., Chicago 7, Ill.*

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Time Switch

New "T-471" time switch automatically controls electrical circuits for one "ON" and one "OFF" operation during any 24-hour period with additional riders available. Has synchronous Telechron movement, is self starting and self lubricated.—*General Electric Co., Meter and Instrument Dept., Schenectady 5, N. Y.*

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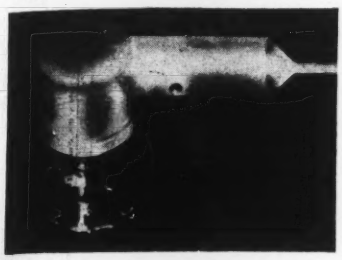
Tube Cap Connector

New "Series 90-ISRL" high-voltage low-loss tube cap connector has ½-watt resistor of any resistance integrally



molded. Fits ¼- and 23/64-inch dia. tube caps. Clip reduces corona. Available in various insulating materials.—*Alden Products Co., 117 N. Main St., Brockton, Mass.*

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Twin Power Triode

New "Type 6080" is low-mu, high-perveance, twin power triode designed primarily for use as regulator tube in stabilized d-c. power-supply units. Is similar to 6AS7-G in characteristics but smaller in size. Compact design improves strength against shock and vibration.—*Tube Dept., Radio Corp. of America, Harrison, N. J.*

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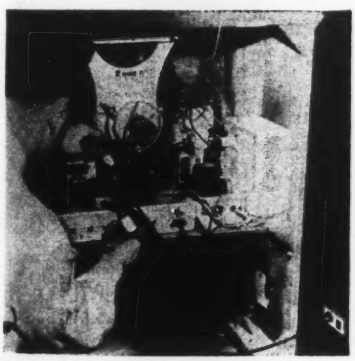
Chassis Servicing Aid

New "Tele-lead" serves as jumper from a-c. power outlet to TV chassis



and also as trouble light of convenient size.—*Cathode-ray Tube Div., Allen B. Du Mont Laboratories, Inc., 750 Bloomfield Ave., Clifton, N. J.*

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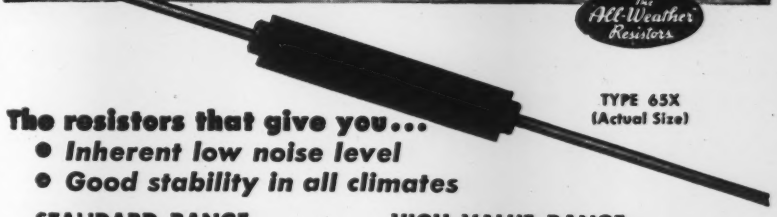

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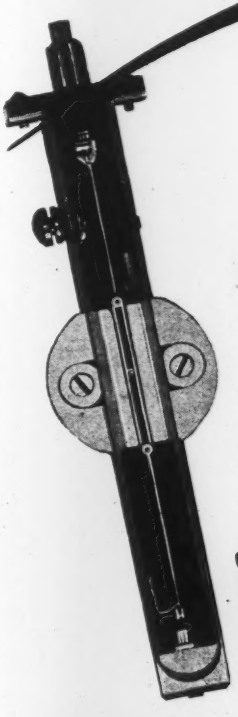

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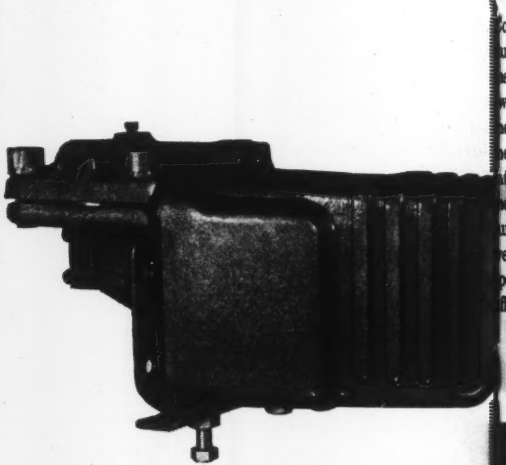

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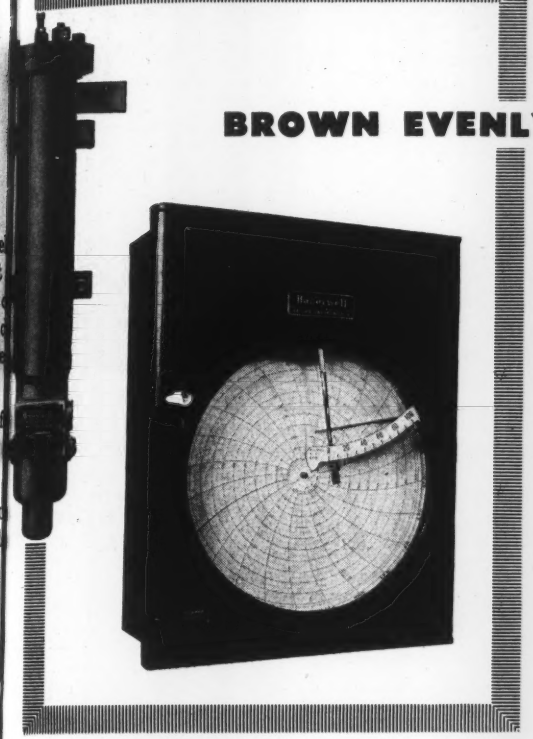

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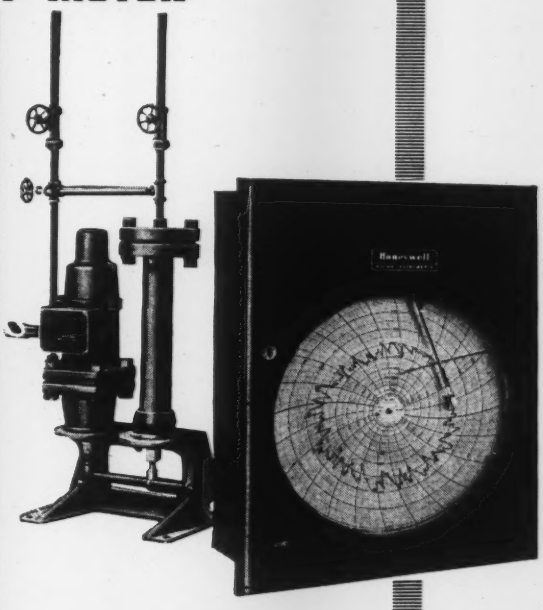

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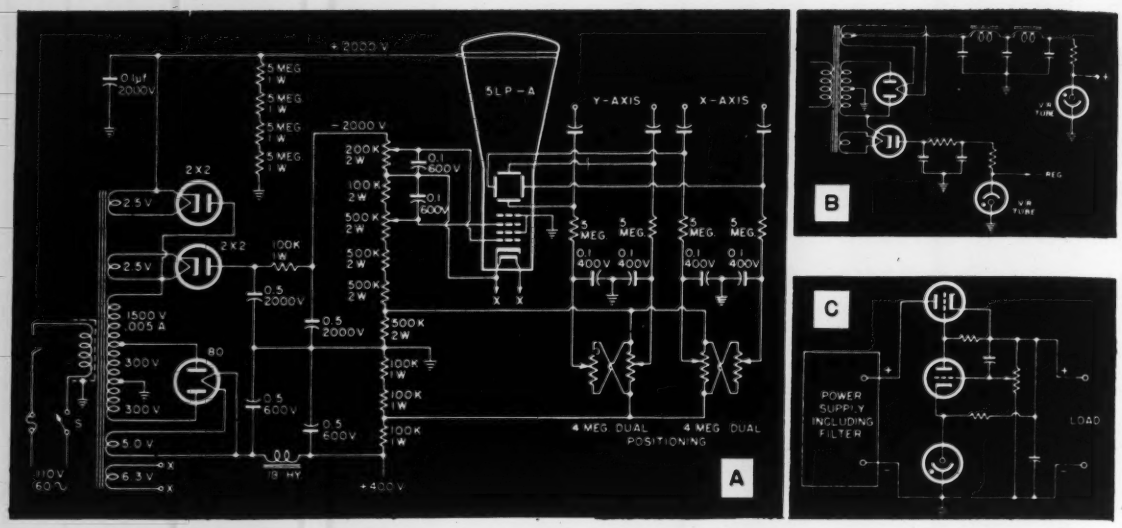


Fig. 7-1. Typical power supplies. A, supply for a cathode-ray tube; B, VR-tube regulated supply; C, electronically-regulated supply. *(Courtesy Allen B. DuMont Labs, Inc.)*

INSTRUMENT ELECTRONICS

A power supply is a basic part of every electronic circuit. Transformers, rectifiers, filters, and typical supplies—regulated and unregulated—are discussed.

By MILTON H. ARONSON
Managing Editor, *Instruments*

VII. RECTIFICATION AND POWER SUPPLIES

BASIC circuits using resistors, inductors, and capacitors are the (1) coupler, (2) differentiator, (3) integrator, and (4) resonant circuit. These circuits were described in Chapter IV. The basic electron-tube circuits are the (1) rectifier, (2) amplifier, and (3) oscillator. All other circuits—limiters, clampers, waveshapers, triggers, multivibrators, counters, etc.—are but variations of these three basic electron-tube circuits. This chapter describes basic rectifier circuits and their principal application—power supplies.

Power supplies provide proper operating voltages to the filament, screen grid, and plate circuit of each vacuum tube used in electronic equipment. The power supplied to the filament usually is alternating current; the power for grid and plate circuits must be as nearly pure direct current as possible.

The d-c. power can be supplied several ways. If the quantity of current needed is not large, batteries can be used. If more power is needed than can be supplied by a battery, a d-c. generator can be used. As both batteries and generators are bulky and unwieldy, most electronic circuits use a power supply that rectifies the output of a commercial a-c. source. Such a power supply consists of four major parts—(1) the transformer, (2) the rectifier circuit, (3) the filter circuit, and (4) the bleeder, or voltage-divider system. A block diagram of a rectifier-type power supply is shown in Fig. 7-2.

TRANSFORMERS

Power transformers are used in power supplies to step the a.-c. source voltage (usually 110 volts) up or down to a desired value. Plate and screen circuits require several hundred d-c. volts. D-c. voltages of several thousand volts are required for the operation of cathode-ray tubes. Filaments require low voltages such as 2.5, 5.0, or 6.3 a-c. volts. Thus the a-c. source voltage must be stepped up for the plate and screen supply, and down for the filament supply. Most power supplies contain a dual-purpose power transformer with windings for both high and low voltages, as shown in Fig. 7-3.

The primary windings of the transformer shown in Fig.

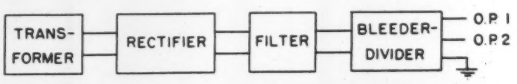


Fig. 7-2. Block diagram of a rectifier-type power supply.

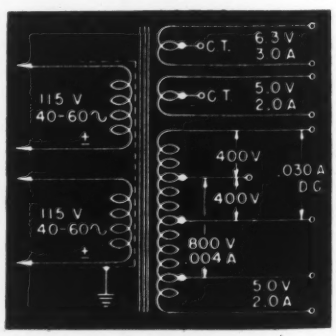


Fig. 7-3. Typical power transformer.

ANSWERS TO QUIZ VI.—GAS-FILLED TUBES

6-1.	(c)	6-6.	(d)	6-10.	(b)	6-14.	(a)	6-18.	(d)
6-2.	(a)	6-7.	(c)	6-11.	(d)	6-15.	(c)	6-19.	(c)
6-3.	(e)	6-8.	(b)	6-12.	(b)	6-16.	(b)	6-20.	(c)
6-4.	(b)	6-9.	(a)	6-13.	(d)	6-17.	(a)	6-21.	(a)
6-5.	(a)							6-22.	(c)

Test Items for VII.—Page 218

7-3 are connected directly to a standard 60-cps. 110-v. outlet. The several low-voltage windings supply a-c. power to the filaments of all tubes in the circuit. The high-voltage windings are connected to the rectifiers in the circuit. The primary or the entire transformer can be shielded to keep the 60-cps. magnetic field from reaching low-level circuits in the equipment.

Phase Inversion

Note that several of the windings are center tapped. The potential of the center tap is always midway between the potential of the outside ends of the winding. Also, the outside ends are always 180 degrees out of phase—that is, *if the center tap is grounded*, the upper end is at a positive peak when the lower end is at a negative peak; on the next half cycle the phase relations are reversed. This characteristic of a transformer provides a simple means for obtaining two voltages which are 180 degrees out of phase. Such voltages are required in many common circuits, including full-wave rectifiers and push-pull amplifiers, as will be described.

Note also that the high-voltage windings supply currents of milliamperes; the low-voltage windings supply currents of amperes.

Rectifiers

A rectifier is a device that converts alternating current into direct current. Any device that conducts current in one direction better than in the reverse direction can be used as a rectifier. As explained previously, the diode is a rectifier because it conducts in only one direction. Other devices that can rectify are (1) metallic-oxide rectifiers, (2) crystal rectifiers, (3) electrolytic rectifiers, and (4) mechanical rectifiers. Electron tubes and metallic-oxide rectifiers are used most widely in electronic power supplies.

Half-wave Rectifiers

Fig. 7-4,A and B shows half-wave rectifiers—that is, rectifiers which conduct only during one half of the applied a-c. cycle. The load can be any device through which it is desired to send direct current. The transformer is used to step the applied a-c. voltage up or down to any desired value.

When 115-volts a.c. is applied to the primary of the transformer in Fig. 7-4,A, a 700-volt rms. a-c. signal is produced across the secondary. On each half cycle when the plate is more positive than the cathode, a pulse of direct current flows from cathode to plate and through the load. Except for the voltage drop across the tube, the peak voltage developed across the secondary appears across the load.

The 7.5-volt secondary heats the filament. Although the filament and plate circuits are at the same d-c. reference potential, the rectified plate current does not flow through the filament circuit.

Fig. 7-4,B shows a half-wave rectifier with an indirectly heated cathode. Note that the plate circuit and filament circuit can be at different reference potentials. This type circuit is used when a lower d-c. output voltage is desired.

The current through the load consists of rectified (unidirectional) pulses of current, which occur at a rate of 60 per second. For most applications, the pulse-type output must be filtered into a smooth d-c. voltage. As the pulses are separated by a period of nonconduction, the half-wave rectified output is difficult to filter.

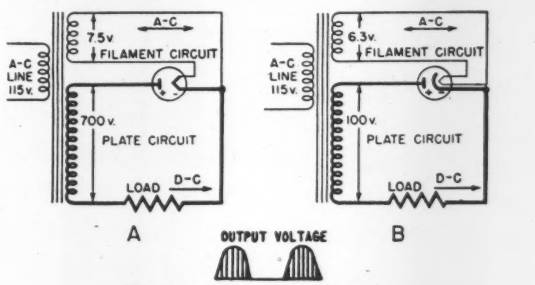


Fig. 7-4. Half-wave rectifiers.

Full-wave Rectifier

A full-wave rectifier has two or more rectifying elements arranged so that the output flows through the load *in the same direction* during both half cycles of the applied a-c. supply. Fig. 7-5,A shows a full-wave rectifier circuit that uses two diodes. The cathodes of the two diodes are connected together and to one end of the load. The other end of the load is connected to the center tap of the transformer secondary.

The center tap usually is the reference point in the circuit—that is, it is grounded so that its potential cannot vary. If the center tap is at a constant potential, one end of the transformer is more positive than the center, and the other end is more negative. On the next half cycle the ends reverse polarity.

When the upper end is positive, the upper diode section conducts, sending a pulse of current through the load. In the next half cycle, the lower diode section conducts, sending another pulse of current *in the same direction* through the load. Thus there are 120 pulses of direct current per second through the load, and no period of nonconduction.

The full-wave rectifier is more efficient than the half-wave rectifier because there are two pulses of positive current in the output for each cycle of a-c. input. As the frequency of the pulse output of the full-wave rectifier is twice that of the half-wave rectifier, the output of the former is easier to smooth out.

The full-wave rectifier can use two separate diodes or one duo-diode tube, as shown in Fig. 7-5,B. The operation is the same because the duo-diode is simply two diodes in one envelope.

Note that the maximum voltage that can be developed across the load is the peak voltage developed across only half the transformer secondary—minus the drop across the tube, of course. Therefore the full-wave rectifier develops a lower voltage across its load than does a half-wave rectifier with the same transformer.

Three-phase Rectifier

For high-power applications, as in industrial welding, the generator usually is a 3-phase generator. Fig. 7-6 shows a half-wave rectifier for a 3-phase source. As in the full-wave rectifier, each diode conducts on a half cycle and sends a pulse of unidirectional rectified current through the load. The dotted curves in Fig. 7-6,B show how each rectifier conducts during one cycle of the applied 60-cycle source; the solid line shows the output.

The a-c. component in the output of a d-c. source is called *ripple*. Note that the ripple voltage in the 3-phase half-wave rectifier is much less than in the 1-phase full-wave rectifier. Note also that the frequency of the ripple voltage

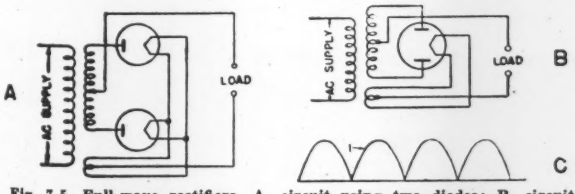


Fig. 7-5. Full-wave rectifiers. A, circuit using two diodes; B, circuit using one duo-diode; C, output.

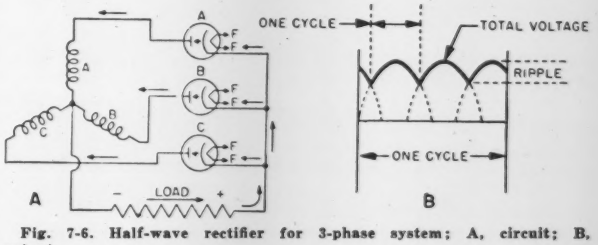


Fig. 7-6. Half-wave rectifier for 3-phase system; A, circuit; B, output.

in the 3-phase half-wave rectifier is 180 cps.; that in the 1-phase full-wave rectifier is 120 cps; that in the 1-phase half-wave rectifier is 60 cps. A more complicated rectifier—the 3-phase full-wave rectifier—has a ripple frequency of 360 cps. As it is easier to filter a high-frequency signal, the full-wave 3-phase rectifier is the easiest to filter. However, as most instrument electronic circuits operate from a single-phase 60-cps. source, the 1-phase full-wave rectifier is the most common rectifier circuit in power supplies.

Metallic-oxide Rectifiers

If certain metals are brought into contact, electrons flow more easily in one direction across the point of contact than in the other direction. Any device with this characteristic is a rectifier because it conducts better in one direction. Two such combinations in general use are (1) the copper-oxide rectifier and (2) the selenium-oxide rectifier. Metallic-oxide rectifiers also are called *dry-plate* rectifiers.

A metallic-oxide rectifier (Fig. 7-7,A) consists of a very thin film of metallic oxide on a round disk of metal. As the thin coating of oxide cannot withstand high voltage (the maximum voltage of a single copper-oxide disk is 11 volts), a number of disks usually are stacked together in

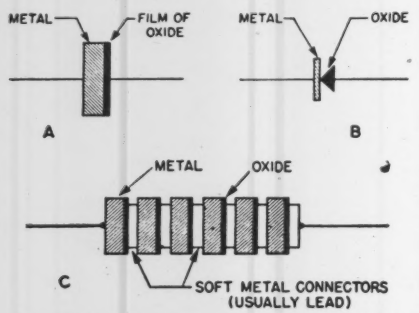


Fig. 7-7. Metallic-oxide rectifiers. A, one element; B, symbol; C, stack.

series, as shown in Fig. 7-7,C. A stack of 10 disks thus can stand 11 x 10, or 110 volts. The symbol for a metallic-oxide rectifier is shown in Fig. 7-7,B. The arrowhead points in the direction in which electrons pass through the rectifier most easily.

The copper-oxide rectifier consists of a thin film of copper oxide on a disk of copper metal; the metal spacer between each rectifier element in the stack usually is lead. The selenium-oxide rectifier consists of a thin film of selenium oxide on a disk of any conducting metal, usually iron or aluminum.

The metallic-oxide rectifier is particularly suitable for supplying a relatively large direct current because the rings of copper and copper oxide may be made large in area, and cooling fins may be incorporated easily in the stack of washers. The resistance of the selenium rectifier in the forward, or conducting, direction is less than that of the copper-oxide rectifier. For this reason, the selenium rectifier is more efficient and can pass a greater current than can a copper-oxide rectifier of similar size. Metallic-oxide rectifiers are used to run small d-c. motors, to operate relays, to supply bias, to charge storage batteries, and as rectifiers in some power supplies.

Rectifier Efficiency

Note that the metallic-oxide rectifier conducts slightly even on the "nonconducting" portion of the cycle. The efficiency of a rectifier can be expressed in terms of the ratio of its resistance in the reverse (nonconducting) direction to its resistance in the forward (conducting) direction. A perfect rectifier would have zero ohms forward resistance and infinite ohms reverse resistance. The metallic-oxide rectifier has a forward resistance of several hundred ohms and a reverse resistance of several hundred thousand ohms. The diode has about the same forward resistance but a higher reverse resistance of several hundred

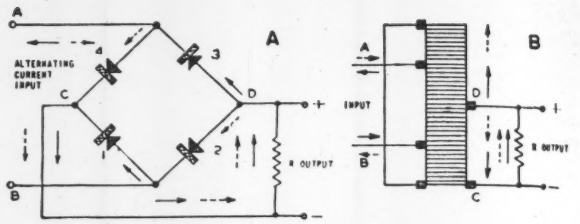


Fig. 7-8. Metallic-oxide rectifiers in bridge circuit. A, circuit; B, connections on rectifier stack.

megohms. Although the metallic-oxide rectifier is less efficient than the diode, it has the advantage of requiring no filament power.

A disadvantage of the metallic-oxide rectifier is a relatively low peak inverse voltage. On the nonconducting half cycles, the inverse voltage across the element must not exceed its rated peak inverse voltage or else break-down occurs. For this reason, dry-plate rectifiers are not used often in either conventional half-wave or full-wave rectifier circuits. They are used commonly in bridge rectifiers.

Bridge Rectifiers

A bridge-rectifier circuit is shown in Fig. 7-8. The input is applied to diagonally opposite corners of the bridge, and the load is connected to the other two corners.

On the first half cycle, electrons flow from point B, through element 1, *up* through the load, through element 3, to point A. On the next half cycle, electrons flow from A, through element 4, *up* through the load, through element 2, to point B. As current flows on both half cycles, the bridge circuit is a full-wave rectifier.

The bridge rectifier has two advantages over a conventional full-wave rectifier. One is that no center-tapped transformer is required. Because of the center tap, the transformer in a conventional rectifier supplies only half its total voltage to the rectifier on each half cycle. In the bridge rectifier, however, the total voltage output of the bridge rectifier is nearly twice that of the conventional full-wave rectifier with the same transformer.

The second advantage of the bridge circuit is that the inverse voltage across each rectifying element is half the inverse voltage impressed across each element in the conventional full-wave rectifier that produces the same output voltage.

A disadvantage of the bridge rectifier is that twice as many rectifying elements are required. Also, if diodes are used as rectifiers, three separate filament transformers are needed because there are three different cathode potentials —and the filament potential cannot be far from the cathode potential. Hence electron tubes are not used as widely in bridge-rectifier circuits as are metallic-oxide rectifiers. The schematic of a metallic-oxide rectifier designed especially for a full-wave bridge-rectifier circuit is shown in Fig. 7-8,B.

Voltage Multipliers

In all the rectifier circuits discussed so far, the output voltage cannot exceed the peak value of the a-c. voltage

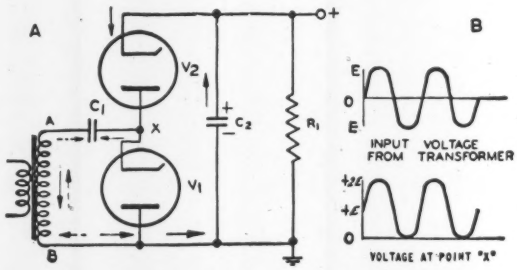


Fig. 7-9. Cascade voltage doubler. A, circuit; B, waveform.

applied to the rectifier. *Voltage multiplier* circuits, however, can produce a d-c. voltage equal to 2, 3, 4, or more times the applied voltage.

Voltage multipliers use capacitors which are effectively in series, charging each on alternate half cycles. For example, in the *cascade voltage doubler* shown in Fig. 7-9, capacitor C_1 is charged to the peak voltage of the applied voltage by diode V_1 when end A of the transformer swings negative. The electrons leave the cathode of V_1 and charge point X to the peak positive value of the applied voltage. On the next half cycle, end A of the transformer swings positive and causes diode V_2 to conduct and charge capacitor C_2 to the peak of the lower waveform shown in Fig. 7-9,B—that is, to twice the peak voltage across AB.

Cascade voltage doublers can be combined in series with half-wave rectifiers and other cascade voltage doublers to produce higher multiplications of the input voltage.

Voltage multiplying circuits are used where it is inconvenient to use a transformer large enough to supply the high voltage required, or where it is desired to obtain sufficient plate voltage to operate small vacuum tubes from a 115-v. a-c. source without using a transformer. The output voltage of all types of voltage doublers drops if the average load current exceeds a few millamperes. Another disadvantage is that a separate filament transformer is required for each tube.

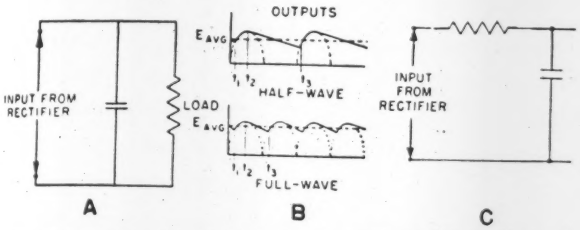


Fig. 7-10. Capacitance filters. A, simple capacitance filter; B, action for half-wave and full-wave inputs; C, resistance-capacitance filter.

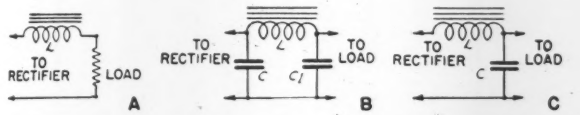


Fig. 7-11. Filters using inductance. A, simple inductance filter; B, capacitor-input inductance-capacitance filter; C, inductance-input inductance-capacitance filter.

Filter Circuits

The output of any rectifier system is a pulsating d-c. voltage. Before the rectified voltage can be applied to plate or grid circuits, it must be filtered into smooth, nonfluctuating direct voltage. Filtering systems, which are made of combinations of capacitors, inductors, and resistors are used to remove the fluctuations, or ripple voltage.

Capacitance Filters

Ripple voltage exists because energy is supplied to the load in pulses by the rectifier. The ripple can be reduced if some energy is stored in a capacitor and is used between the pulses of energy from the rectifier. Fig. 7-10,A shows a capacitance filter. The output voltage of the rectifier is applied across the filter capacitor and load. The capacitor charges to the peak voltage of the rectifier within a few cycles after the start of operation. The charge on the capacitor is stored energy. When the voltage output of the rectifier declines, the voltage on the capacitor does not follow immediately because reverse current cannot flow through the rectifier. The energy stored in the capacitor then discharges through the load. Therefore the voltage across the capacitor falls off slowly if a large capacitor is used and if the load current is small (Fig. 7-10,B). If the resistance of the load is small, the heavy current drawn by the load causes the average d-c. voltage to fall. For this reason the simple capacitor filter is not used with rectifiers that must supply a large load current. However, the use of a capacitor for filtering high-frequency signals is one of the basic uses of capacitors.

Resistance-capacitance Filters

For some applications a filter circuit consisting of a resistor and a capacitor is used. In the circuit shown in Fig. 7-10,C, a large capacitor with a low impedance (about 500 ohms) to the 60-cps. ripple frequency is used. A resistor with a resistance of about 50,000 ohms is used. Therefore only 1 percent of the ripple voltage appears across the capacitor because of voltage-divider action. As the capacitor has infinite impedance to the direct voltage, however, the direct current flows through the resistor. The current through the resistor cannot be large or the voltage output of the filter drops because of the IR drop across the resistor. For this reason the resistance-capacitance filter is not used where large load currents are required. The filter is used commonly for supplying screen-grid potentials of pentodes, and for filtering higher-frequency signals in radio and instrument circuits.

Inductance Filters

An inductance in series with the rectifier output (Fig. 7-11,A) prevents abrupt changes in current. The smoothing action that results is due to the inductor, the reactance of which opposes any change of current through it.

The inductance prevents the load voltage from reaching the value that would be reached without the inductance. As the output voltage never reaches the peak value of the applied input voltage, a rectifier used with an inductor filter cannot produce as high a voltage as it would with a capacitor filter. However, the inductor permits a large load current to flow without serious loss in the output voltage because the IR drop across the inductor is small.

Inductors that are used in filter circuits are called *chokes* because they choke, or stop the passage of, the ripple voltage into the load.

Inductance-capacitance Filters

The ripple voltage in a rectifier output cannot be made smooth enough for most circuits by either a simple capacitor, a resistance-capacitance filter, or an inductance filter. More effective filters can be made if both inductors and capacitors are used, as shown in Fig. 7-11,B and C. Fig. 7-11,B shows a capacitor-input filter—that is, one in which the voltage input to the filter is fed into the capacitor.

Capacitor C has an infinite impedance to direct voltage. However, it has a low impedance to the ripple voltage. Therefore most of the ripple voltage is bypassed to ground by capacitor C. Inductor L offers a high impedance to the remaining ripple voltage. The small ripple voltage that remains at the output side of L is shunted to ground through C_1. The result is that the output voltage has little ripple.

The *inductor-input filter* shown in Fig. 7-11,C differs from a capacitor-input filter because the voltage input to the filter is fed into an inductor. The input inductor keeps capacitor C from charging to the peak value of the applied voltage. Therefore the output voltage of a choke-input filter is lower than that of the capacitor-input filter. However, the output potential of the choke-input filter is much less affected by changes in load—that is, the filter has good regulation.

Regulation

The terminal voltage decreases when a load is placed on the power supply. The decrease of voltage, expressed in percent, is called *regulation*. It is given by the following equation:

$$\text{Percent regulation} = 100(E_1\text{-}E_2)/E_2,$$

where E_1 is the no-load voltage and E_2 is the full-load voltage. A circuit has poor regulation if a large drop in the output voltage occurs when full load is applied.

The capacitor-input filter is not suited for applications that require large current because the output voltage falls as the load increases—that is, the capacitor-input filter has

poor regulation. This type of filter ordinarily is used where the load is light or constant. Except for a large change in voltage near zero load, the output voltage of the choke-input filter changes very little over a wide range of current. Hence this type filter has good regulation. In practice, a resistor usually is placed across the output to prevent the initial change in voltage that takes place when a load is first applied.

Because of their good regulation, choke-input filters are used in circuits where the load changes appreciably. They are used also to filter the output of gas tubes because gas tubes have (1) very low plate resistance and (2) stray transients in their rectified output. If a capacitor-input filter were used with a mercury-vapor rectifier, the low plate resistance and the stray transients would cause large alternating currents to flow through the input capacitor and would damage the tube.

Effect of Frequency on Filtering Action

Most power supplies are designed for operation with 60-cps. alternating current. If the frequency of the output voltage is increased, all components can be made smaller and lighter because, as the frequency increases, the reactance of a given capacitor decreases and the reactance of a given inductor increases. Therefore a given filter is more effective when the frequency of the input voltage is increased.

Similarly, adequate filtering can be obtained with less inductance and capacitance when the input frequency is higher. If less inductance is needed in the filter, smaller and lighter choke coils can be used. To save weight and space, aircraft power supplies are designed to operate from an 800-cps. source. Most commercial instruments, however, are limited to the use of commercial 60-cps. power.

Voltage Dividers

A resistor is almost always placed *across* the output of a power supply to discharge the filter capacitors after the supply is turned off. This is a safety precaution. Such a resistor is called a *bleeder resistor* because it permits the charge on the capacitor to "bleed," or decay slowly. As bleeder resistors usually have a high resistance, they draw only a small current from the supply.

If the resistor across the output applies a fixed load to the filter circuits to improve regulation, it is called a *loading resistor*. A loading resistor should draw about 10 percent of the full-load current, and it should have sufficient power rating to dissipate the heat produced by the current. Both bleeders and loading resistors may have taps connected at various points to provide several voltages to its circuit. A resistor with such taps is called a *voltage divider*.

Typical Supplies

Fig. 7-1,A shows a power supply for a cathode-ray tube, such as is used in oscilloscopes, radar, television, etc. The full-wave rectifier uses a type-80 duo-diode. The center-tapped 300-v. transformer develops the positive 400-v. supply, which is used to supply the plates and screens of the several electron tubes in the circuit of which the cathode-ray tube is a part. The filter for this supply is a capacitor-input inductance-capacitance filter.

The power transformer has a 1500-v. winding which is connected to two type-2X2 half-wave rectifiers. The lower 2 X 2 produces a negative 2000-v. supply, which is filtered in a resistance-capacitance filter. This type filter can be used because the supply produces only a few milliamperes for the electrodes of the cathode-ray tube.

The upper 2X2 produces a positive 2000-v. supply for the high-voltage intensifier electrode. As negligible current (microamperes) is required for the intensifier, a simple capacitor filter can be used. The bleeder resistor for this supply is 20 megohms. Four 5-megohm resistors are used to divide the voltage drop across each resistor to prevent arc-over.

The negative 2000-v. supply is fed to a voltage-divider network which supplies the proper potentials to the cathode, control grid, and focusing electrode (grid 3) of the cathode-ray tube. The second grid, or accelerating electrode, is at ground potential. Note that the accelerating electrode is much more positive than the grid and cathode, which are at the high negative potential. Note also that the total voltage from cathode to intensifier electrode is 4000 volts. The voltage is divided into a positive and a negative 2000-v. supply for safety purposes. Also, the deflection plates are close to ground potential in this supply. This is desirable because the signal to be observed in the oscilloscope can be applied directly to the plates. This could not be done if the plates were at a high positive voltage.

The voltage-divider network to the right of the cathode-ray tube provides a variable voltage (near ground potential) to the deflection plates. The voltage is variable so that the spot on the tube can be positioned vertically and horizontally.

Regulated Supplies

A typical *gas-tube-regulated power supply* is shown in Fig. 7-1,B. The full-wave rectifier feeds a 2-stage inductance-capacitance filter. The output, which is a current of several hundred milliamperes, is regulated by the dropping resistor and VR tube, as described previously. The half-wave rectifier produces a negative voltage for low-current bias purposes. Hence a resistor-capacitor filter is adequate.

Fig. 7-1,C shows an *electronically-regulated power supply*. The output of the power-supply filter is delivered to the load through the plate resistance of the upper tube. The plate resistance of this upper tube is controlled by the amplifier tube in the middle, which detects any change in output voltage, amplifies the change, and changes the bias of the upper tube. This controls the plate resistance of the upper tube. The lower tube is simply a reference-level tube which raises the cathode of the amplifier tube up to the voltage required for proper operation. This circuit furnishes a constant voltage to the load despite variation in line voltage or load current.

Commercial power supplies, both regulated and unregulated are available in wide ranges of current, voltage, degree of regulation, and number of outputs.

Vibrator Power Supplies

Sometimes it is necessary to operate a circuit from a d-c. source, such as a 6-volt storage battery. A vibrator can be used to interrupt the d-c. voltage to produce an a-c. voltage, as shown in Fig. 7-12. The vibrator is a solenoid-type relay with a set of contacts. When current flows through the solenoid, contact 1 is closed, sending a pulse of current through the upper half of the transformer.

When contact 1 is closed, the solenoid coil is shorted over, releasing contact 1 and making contact 2. This causes a pulse of current through the lower half of the transformer. The pulses of current are amplified, rectified, and filtered as in conventional full-wave supplies.

A similar supply uses a vibrator with two sets of contacts which cause the current to flow through the secondary of the transformer in one direction only. This type supply requires no rectifier tube. It is called a *synchronous*, or self-rectifying, vibrator power-supply because rectification is done by closing two sets of contacts in synchronization.

Continued on page 218

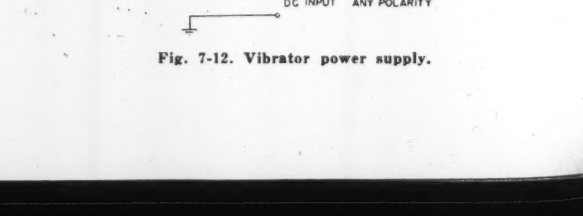
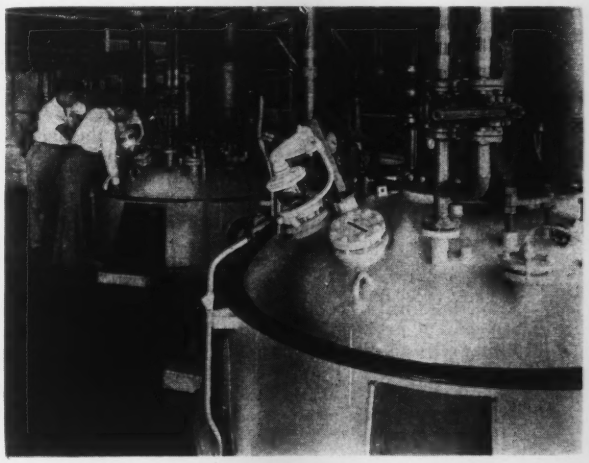


Fig. 7-12. Vibrator power supply.

INSTRUMENTATION of a Synthetic-Rubber Plant

By J. S. DETWILER
Taylor Instrument Companies



Synthetic-rubber reactors at Copolymer Corp. plant, Baton Rouge, La.

Development of the control system for the synthetic-rubber reactor shows how experience and design entered into the solution to a difficult problem. The reactor control system and the complete synthetic-rubber process are discussed.

ALTHOUGH there are many types of synthetic rubber, none is identical with natural rubber. Laboratories never have duplicated the natural rubber molecule. Synthetic rubbers are rubber-like materials made by chemical processes, and possess properties similar to those of natural rubber. Some of the characteristics of synthetic rubber are superior and some are inferior to those of natural rubber.

History

Research in synthetic rubber began in 1826, when the composition of natural rubber was determined by Faraday as being five atoms of carbon and eight of hydrogen. The development of the synthetic rubbers was not done by any one man or country. For more than 100 years, major contributions were made by chemists of Great Britain, France, Germany, and the U. S. A.

By 1923, one American company produced a butadiene synthetic rubber latex by emulsion polymerization in a soap solution. However, the price of natural rubber sank so low during the late 20's that many laboratories abandoned work on synthetic rubber. Germany continued its research and produced commercial synthetic rubber in 1935.

This country produced the first commercially successful substitute for natural rubber in 1932. This was Neoprene, then called Duprene, made by duPont.

Before the last war our inventories of crude rubber were relatively low. At the time of Pearl Harbor our national stockpile was about 500,000 tons, less than a one year's normal consumption. Thus it was necessary to freeze this stockpile and to undertake the development of a synthetic-rubber industry posthaste.

The speed and extent of the wartime conversion from natural to synthetic rubber, combined with conversion from peacetime to war products, is probably the greatest revolution experienced by any industry. It can be said safely that the creation of our great synthetic-rubber industry is, in terms of size and speed, one of the greatest chemical-engineering achievements of all time.

The significance of this was well expressed in the Rubber Reserve Company report in February 1945: "It was necessary to accomplish in less than two years a swift acceleration of the small synthetic rubber industry to the status of a great and going essential industry, and to condense into that brief time technical and commercial developments which under normal circumstances might easily have taken twenty years or more."

In March 1941, Rubber Reserve requested four large rubber companies to submit proposals for four synthetic-rubber plants, each designed for 2500 tons annual capacity. In May 1941 the program was authorized and called for each of the four plants to have 10,000 tons annual capacity. Immediately after Pearl Harbor the program was increased to a total of 400,000 tons per year, and this was stepped up to 805,000 tons per year after the fall of Singapore in early 1942.

GR-S Process

The type of synthetic rubber selected to replace natural rubber in tires and most other applications was GR-S, or Government Rubber, Styrene type. It is a copolymer produced by the polymerization of approximately 3 parts of *butadiene* with 1 part of *styrene* in a soapy emulsion containing catalysts and modifiers in order to obtain a proper reaction.

Butadiene is made by several different methods from alcohol and petroleum. Petroleum-base butadiene is produced from n-butylenes which are catalytically cracked at high temperature in the presence of steam, and then purified by fractional distillation and absorption.

Styrene is manufactured by alkylating benzene with ethylene and catalytically cracking the ethyl benzene produced to yield crude styrene, which then is refined by vacuum fractionation.

Presented at the A & M College of Texas' Sixth Symposium on "Instrumentation for the Process Industries," Houston, Tex., Sept. 10-14, 1951.

The liquid styrene and the gas butadiene, in liquid form, and under pressure, are piped or shipped to the copolymer plant and stored in large storage tanks. Temperatures are guarded carefully and water sprays are used for cooling when necessary. Some butadiene tanks are submerged in water underground to lessen the explosion hazard.

Reactors

The raw materials, together with the soap solution, catalyst, modifiers, and other chemicals are then metered into the reactor. This metering has been done by displacement meter, rotameter, and proportioning-pump systems.

Standard plant reactors have a capacity of approximately 4000 gallons. They are glass lined, water jacketed, and equipped with motor-driven agitators. The circulating water is pumped into the jacket through several nozzles. Steam or cooling water is admitted to the circulating system. The jackets are open to the atmosphere and provided with an overflow return pipe to the pump suction. The control valves are in the steam and water inlet lines.

Temperature Control of Reactors

The time lags in the reactor system create a difficult temperature-control problem. The transfer lags are composed of (1) the velocity-distance lag, (2) the water-jacket film-coefficient lag, (3) the transfer lag through the metal, glass lining, and a slight coating of rubber and the well, and (4) bulb lags. There is also the capacity lag of both the supply and demand sides.

The temperature control of the reactor is highly important, and a great amount of development and experimental work was done prior to the evolution of the so-called "standard plant." Polymerization was done in the reactors on a batch basis throughout the early design period and continued on that basis when the standard plants were put into operation. However, research was under way for continuous polymerization and some plants were converted after the war ended.

Our first experience on temperature control of synthetic-rubber pilot-plant reactors was in 1940. The instrument used first was an adjustable-sensitivity plus automatic-reset controller with its bulb in a well in the product. As the reaction was violent once started, this type of controller was wholly inadequate for the job. Owing to the inherent lag in heat transfer and to the capacity effect, the temperature could not be checked without considerable overpeaking, which was dangerous. If the temperature was not checked at the polymerization temperature, the reaction became so violent that it was virtually impossible to stop it, and the reactor had to be discharged.

The next scheme of temperature control tried was that shown in Fig. 1. A double-duty controller was used. One system (with automatic reset) had its bulb in the product; the second system (with proportional response) had its bulb in the jacket circulating water. This system of control was designed to maintain the jacket circulating water at some desired value as the reactor temperature increased. When the product temperature reached its desired value, control was shifted to the system having its bulb in the product, which then was controlled at the desired final temperature.

Control of the reactor by this method was not a success because of inherent overpeaking of the temperature (Fig. 2). The overpeaking was caused by automatic reset. If the jacket temperature was controlled at a lower value in order to allow the temperature of the reactor to rise more slowly and cut down the overpeaking, the reaction became too slow. The solid line in Fig. 2 is product temperature. The dotted line is jacket water temperature.

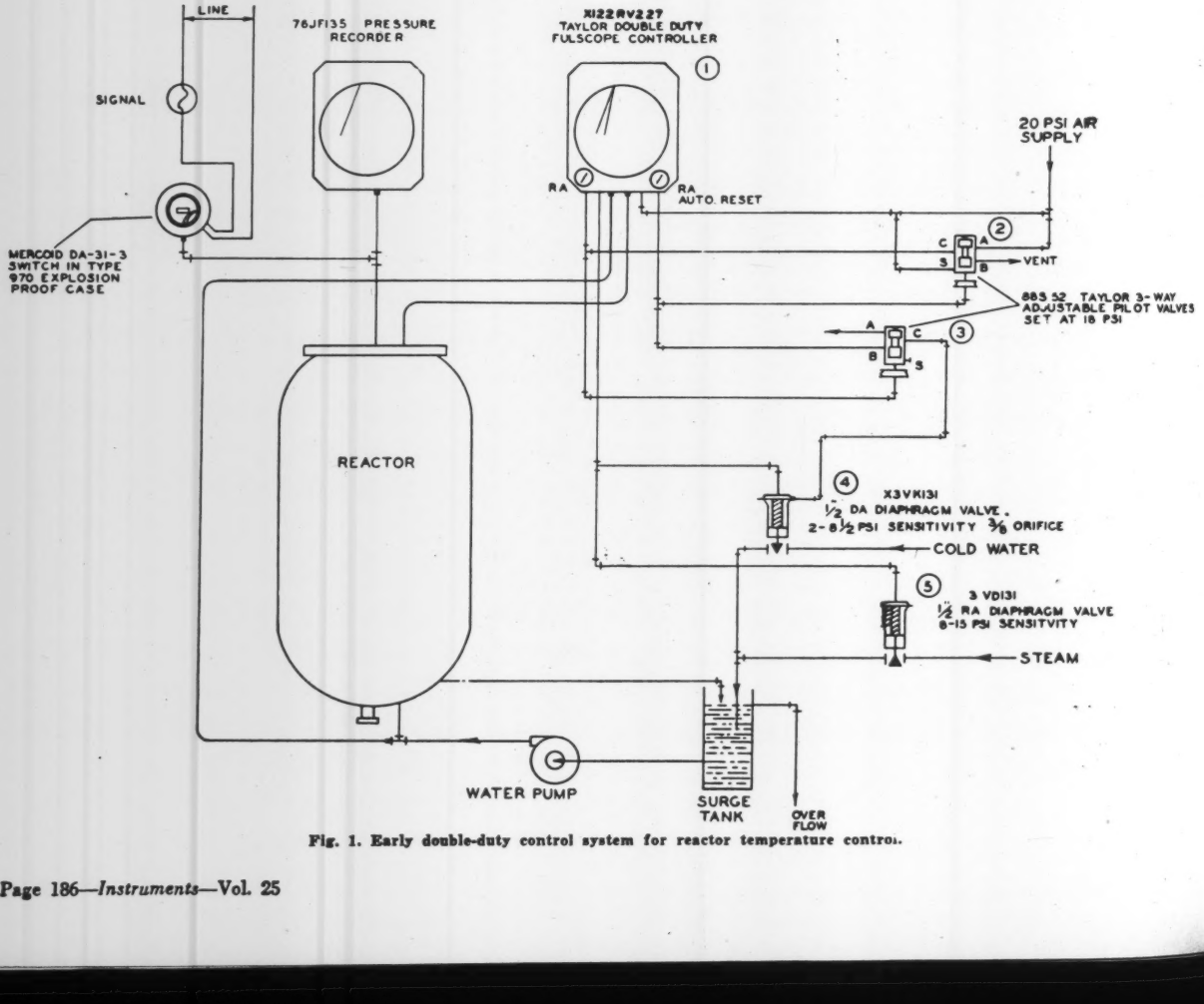


Fig. 1. Early double-duty control system for reactor temperature control.

Ratio Control System

The next approach to the control of the reactor (Fig. 3) used a ratio controller with automatic reset. The adjusting system bulb was in the reactor and set the control point of the circulating water.

During this period of development the reactors were charged so that an exothermic reaction started immediately and became successively violent. Some cooling was constantly required.

At the start of operations, the product temperature was low. By means of adjustable stops in the instrument, the water-temperature control point was set at some desired value until the reaction started.

As the reaction progressed, the water temperature was maintained at the initial value until the product temperature reached a predetermined point. During the reaction, water was admitted to the circulating system to maintain the desired temperature. At the predetermined product temperature, the control point was set up gradually and in a definite ratio as the product temperature increased. More cold water was constantly required as the reaction continued. This was taken care of by the automatic-reset feature of the controller, which allowed the valve to open wider and maintain the desired water temperature.

When the desired top product temperature was reached, further upward adjusting of the water control point was prevented by an adjustable stop in the controller. The water temperature was maintained at that value during the remainder of the reaction, which temperature held the product at approximately the desired temperature, but there was an upward drift because the exothermic reaction was not constant. The flow of cooling water was reduced automatically as the reaction dissipated itself. The results are shown in Fig. 4.

During normal operation, control was obtained by the 1/2-in. water valve. However, if, due to the reaction, more water was required, the 1-in. valve opened to prevent excessive product temperature or a dangerously high pressure in the reactor.

The "on-off" type pressure controller recorded the reactor pressure and, through the pilot valve, blew a whistle if the reactor pressure reached a predetermined maximum.

This system of control was reasonably satisfactory as long as the reactor was carefully and uniformly charged. It could not care for all the variations which were taking place during this development period unless controller and set point adjustments were varied from batch to batch. Differences in charging produced varying reactions and, consequently, different jacket temperatures were necessary to hold the same product temperature.

Time-schedule Control System

Fig. 5 shows the next system of control which was used. It was felt that better control of the reaction could be obtained by bringing the temperature up on a time-schedule basis. The controller was operated at fairly high sensitivity, which resulted in satisfactory product temperature control—but at the expense of large fluctuations of circulating water in the jacket (Fig. 6). Overpeaking of the final temperature was eliminated, but product temperature is not the only thing to be considered. Large and sudden jacket-water temperature changes are detrimental to the product. Initial overheating of the batch causes loss of product, and sudden cooling of the reactor lining causes a pre-coagulation and build-up of rubber in the lining, which impairs the heat transfer. The resulting control was unsatisfactory and the system was abandoned.

System With Ratio Controller Set By Master Controller

A control system similar to Fig. 7 was used next. In this system, the master controller (5) was equipped with adjustable sensitivity and automatic reset. This instrument, with its bulb in the reactor, pneumatically set the control point of the jacket-water temperature controller (6), which was a proportional-type controller.

The automatic-reset feature in the master controller produced any output air pressure necessary to set the water-temperature controller to the water temperature required to maintain the product temperature under any load condition. This, of course, was limited to the range of water

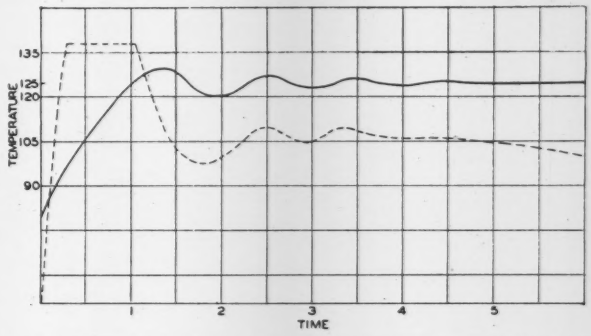


Fig. 2. Control of product and jacket-water temperature achieved by double-duty controller. Time scale is in hours.

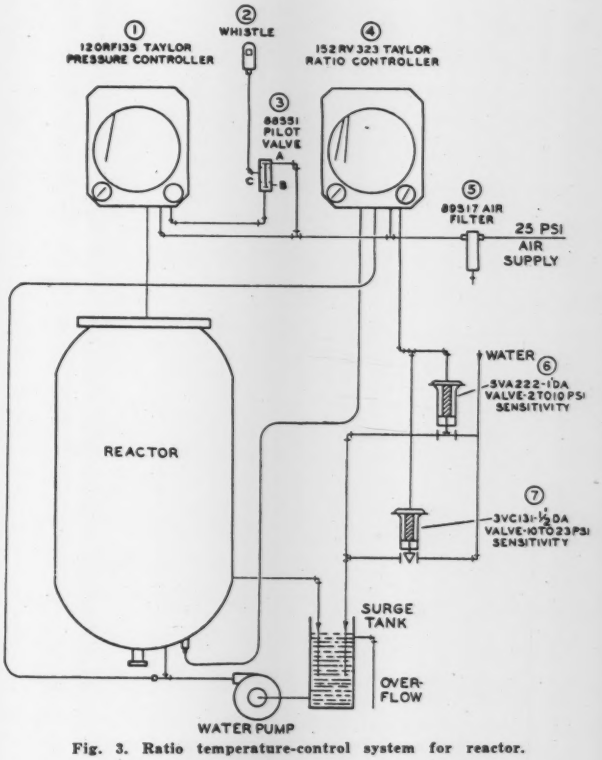


Fig. 3. Ratio temperature-control system for reactor.

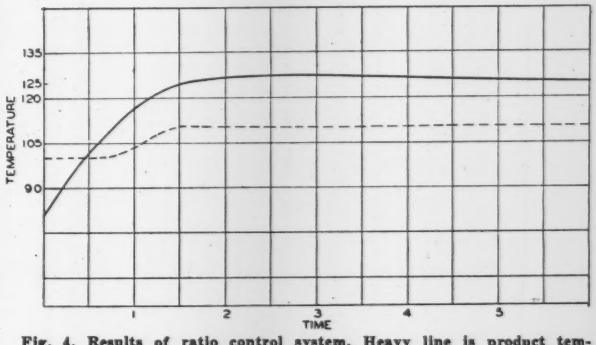


Fig. 4. Results of ratio control system. Heavy line is product temperature; dotted line is jacket-water temperature. Time scale is hours.

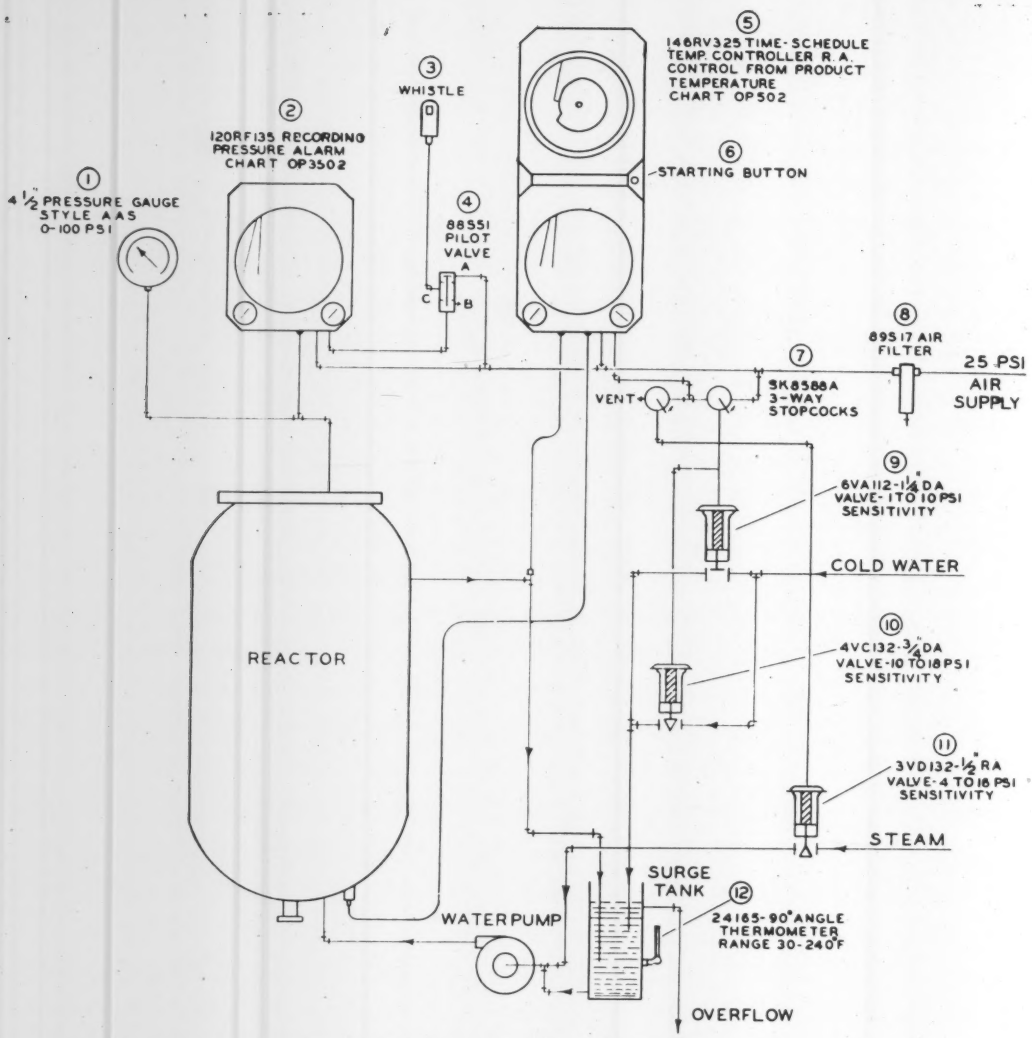


Fig. 5. Time-schedule control system for reactor.

temperatures possible within the capacity of the diaphragm valves and the steam and water supplies available.

At the start of operations, the product temperature was low, and the output air pressure from reactor-temperature controller (5) was high, thus setting the water-temperature controller to a high value. This closed both water-inlet valves (8) and (9), and opened steam valve (10) to heat the circulating water to the value required.

As the reaction progressed, and the product temperature rose, the output air pressure from controller (5) remained at a high value, calling for a high water-temperature. This value could be limited by stops in the pneumatic-set controller (6). Owing to the automatic-reset feature in (5), the output air pressure remained high until the product temperature reached the control point and went above it. Overpeaking of the product temperature resulted and the return to the desired control point was slow, with a long cycle. To avoid this condition, and to break the reaction so as to avoid overpeaking, the operator was required to manually adjust controller (5) to set the water-temperature control point as desired, to accomplish the break. The water-temperature controller admitted either steam or cold water to maintain the circulating water at its control point.

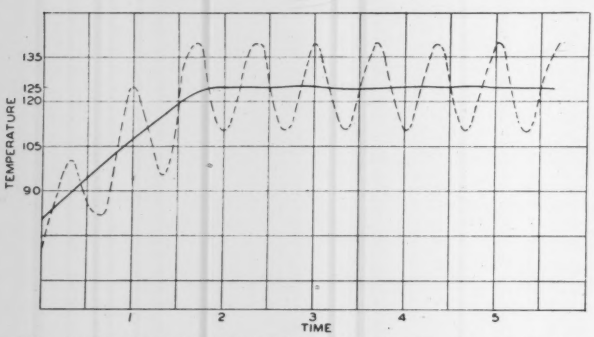


Fig. 6. Product and jacket-water temperatures produced by time-schedule control system. Time scale is in hours.

After the product-temperature control point was reached, the instruments maintained this temperature automatically, compensating for load changes brought about by the reaction. The control obtainable is shown in Fig. 8.

Obviously, the operator attention required to manually adjust the set point was objectionable. However, the overpeaking of the temperature had to be avoided.

The master controller (5) in Fig. 7 was changed from proportional plus reset response to proportional plus derivative; its output pressure still was used to set the water-temperature controller. With this system, as the product-temperature control point was approached, the derivative

effect became effective and quickly set the control point of the circulating water to a lower value. This checked the temperature and prevented overpeaking. The "Pre-Act," or derivative response, produced an output pressure (additive to the proportional response) the magnitude of which was proportional to the *rate* of pen movement.

Owing to the addition of rate response to this system, the sensitivity of the master controller (5) can be raised considerably without causing instability of control. Therefore, large water-temperature control-point adjustments in the pneumatic-set controller (6) were obtained for small product-temperature changes. Thus, overpeaking of the final polymerization temperature was eliminated by the use of derivative action, and drift of the holding temperature caused by load changes during the reaction was negligible because of the high sensitivity possible with the pneumatic-set system.

From the results obtained (Fig. 9). this was the most flexible and most easily adjusted control system for the reactor. It automatically handled wide variations in the charging techniques.

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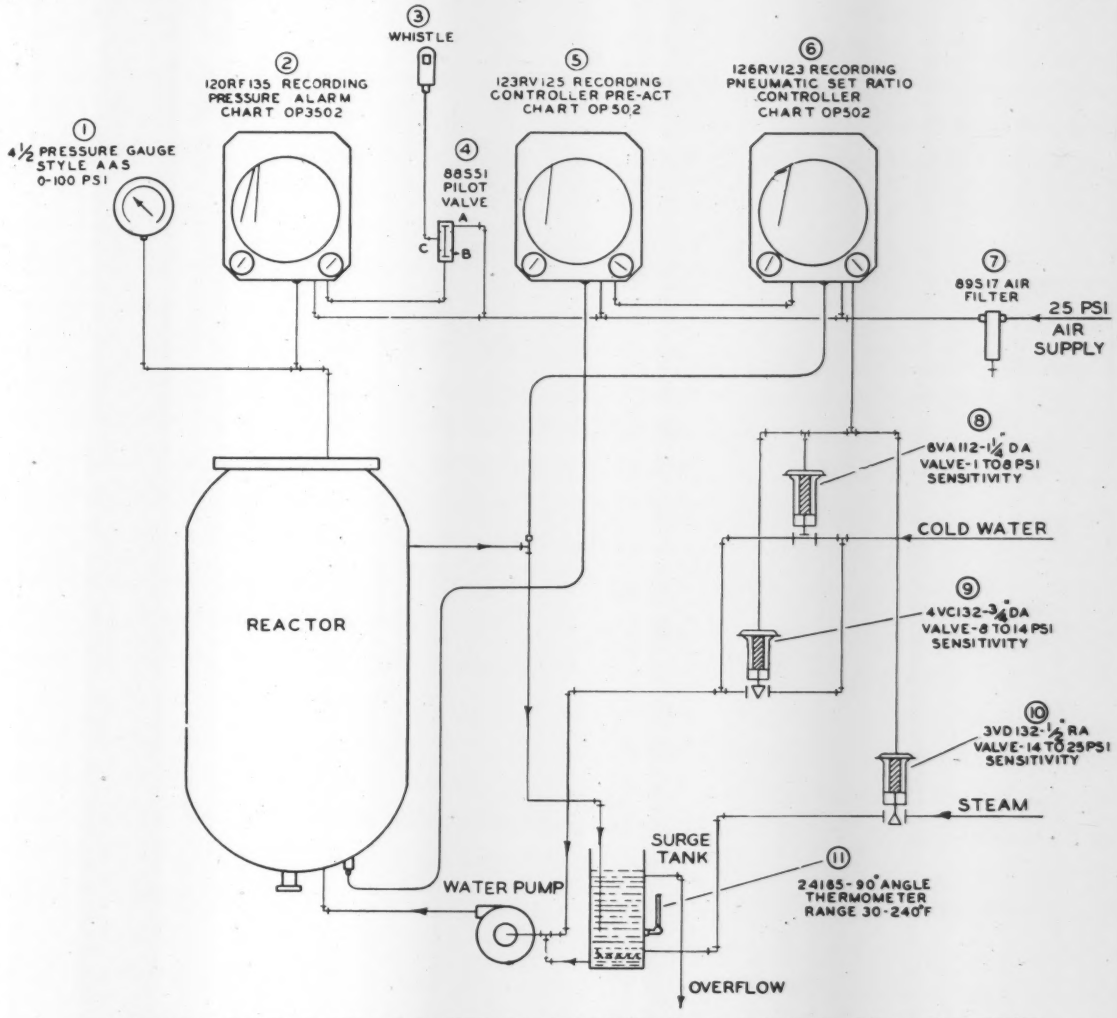

Fig. 7. Reactor control system using a pneumatically set ratio controller whose control point is set by a master controller.

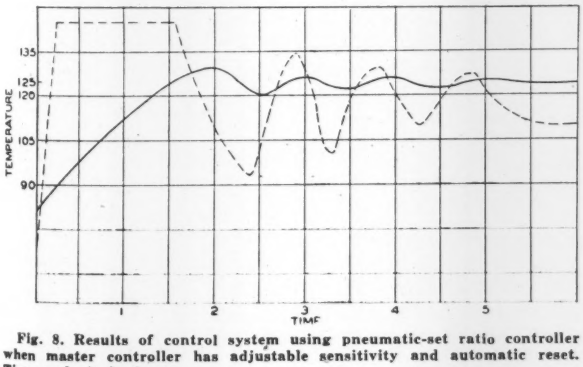

Fig. 8. Results of control system using pneumatic-set ratio controller when master controller has adjustable sensitivity and automatic reset. Time scale is in hours.

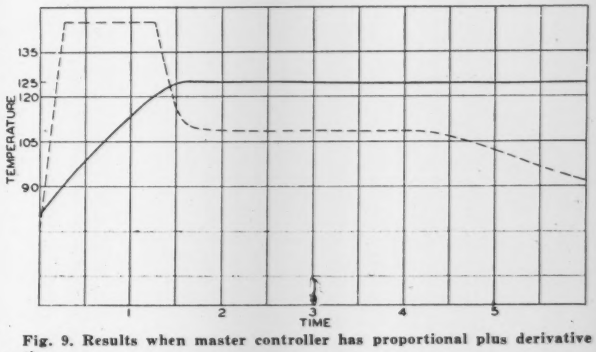

Fig. 9. Results when master controller has proportional plus derivative action.

OPTIMALIZING SYSTEM for PROCESS CONTROL

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Editor's Note: This is the second installment of Mr. Li's article. The first installment appeared last month.

Continuous-test-signal Controller

In a continuous-test-signal controller the system sensitivity is obtained by applying a sinoidal test signal and correlating the output variation of the controlled system with the sinoidal input variation. It has been shown that the sensitivity of a controlled system can be represented by the ratio of the output rate to the input rate. When a sinoidal test variation is used, the average ratio of output rate to input rate is essentially proportional to the average ratio of the output test-signal to the input test-signal. Furthermore, when the amplitude of the input test-signal is constant, the average ratio of output test-signal to input test-signal is proportional to the average product of the output test-signal and input test-signal. To summarize this statement: The sensitivity of the controlled system is proportional to the average of the product of the sinoidal input test-signal and the corresponding output signal.

Fig. 10 is a functional block diagram of a controlled system with an optimalizing controller of the continuous-test-signal type. Fig. 11 is a performance diagram showing the essential actions that occur when the complete system is in operation. The *test-signal generator* of Fig. 10 produces a sinoidal output of constant amplitude and frequency, which is shown in Fig. 11a. This test signal is amplified by a power amplifier and is then applied to the *adjustor drive*, which imposes a constant-amplitude sinoidal component on the controlled input. This input test-variation is shown as the sinoidal component of the controlled input in Fig. 11b. The output of the controlled system (Fig. 11e) depends on the shape of the static characteristic curve of the system (Fig. 11c).

The *output receiver* of Fig. 10 takes the output of the controlled system and generates the output signal, which is shown in Fig. 11e. This signal is supplied to the *band-pass filter* of Fig. 10, which separates the fundamental component of the test-signal output from the smoothed output signal, which latter is essentially equal to the average level of the output signal. The filter suppresses both high-frequency components of the test-signal output and high-frequency interference components.

The output of the band-pass filter is shown in Fig. 11f. This fundamental-frequency test signal passes through the phase adjustor, which compensates for undesirable phase shift introduced by operation of the controlled system. The phase-adjusted signal is supplied to the rectifying multiplier of Fig. 10, which also receives the input test signal. The rectifying multiplier takes the product of these two signals and gives the resultant an algebraic sign by using phase-sensitive rectification of the output signal with respect to the input test signal. The full-line serrated curve of Fig. 11g shows instantaneous values of the rectified *product signal*.

In order to prepare this signal for use as the controlling signal, it is passed through the smoothing filter shown in Fig. 10, which produces the *input correction signal*. This signal is identical with the effective product signal in Fig. 11g. The input correction then is amplified in the drive-signal generating system of Fig. 10, which produces the input signal for the adjustor drive. This causes the controlled-input adjustor to change the average level of the controlled input, as shown in Fig. 11b. The average input level (acting through the characteristic curve of Fig. 11c) produces a smoothed output level that corresponds to the *smoothed output signal* of Fig. 11e. By properly connecting the operating components of Fig. 10, the average input level may be made to cause the output to approach the optimum point so that the general purpose of optimalizing control is fulfilled.

The performance diagram of Fig. 11 was constructed under the assumption that the correction signal to the input-adjustor drive of Fig. 10 produces an input adjust-

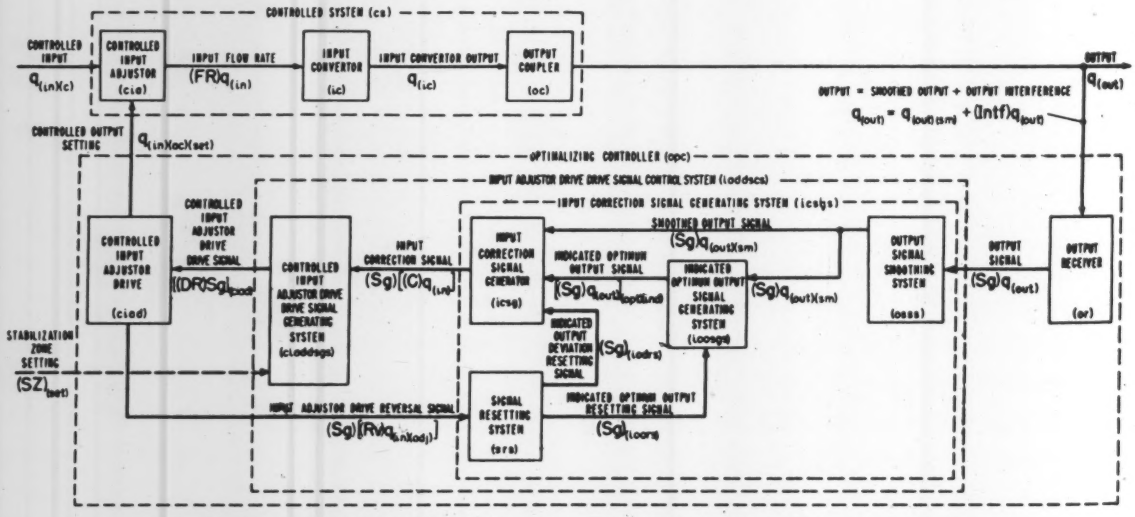

CONTROLLED SYSTEM (cs)
CONTROLLED INPUT
CONTROLLED INPUT ADJUSTOR (cia)
INPUT FLOW RATE
INPUT CONVERTOR (ic)
INPUT CONVERTOR OUTPUT
OUTPUT COUPLER (oc)
OUTPUT
OUTPUT = SMOOTHED OUTPUT + OUTPUT INTERFERENCE
CONTROLLED OUTPUT SETTING
OPTIMALIZING CONTROLLER (opc)
INPUT ADJUSTOR DRIVE DRIVE SIGNAL CONTROL SYSTEM (iadscs)
INPUT CORRECTION SIGNAL GENERATING SYSTEM (icsgs)
CONTROLLED INPUT ADJUSTOR DRIVE (ciad)
CONTROLLED INPUT ADJUSTOR DRIVE SIGNAL
CONTROLLED INPUT ADJUSTOR DRIVE SIGNAL GENERATING SYSTEM (ciadsgs)
INPUT CORRECTION SIGNAL
INPUT CORRECTION SIGNAL GENERATOR (icsg)
SMOOTHED OUTPUT SIGNAL
INDICATED OPTIMUM OUTPUT SIGNAL
INDICATED OPTIMUM OUTPUT SIGNAL GENERATING SYSTEM (iosgs)
OUTPUT SIGNAL SMOOTHING SYSTEM (osss)
OUTPUT SIGNAL
OUTPUT RECEIVER (or)
STABILIZATION ZONE SETTING
INPUT ADJUSTOR DRIVE REVERSAL SIGNAL
INDICATED OUTPUT DEVIATION RESETTING SIGNAL
INDICATED OPTIMUM OUTPUT RESETTING SIGNAL
SIGNAL RESETTING SYSTEM (srs)

Fig. 10. Functional block diagram of a continuous-test-signal-type optimalizing-control system.

ment rate proportional to the input correction signal. (A feedback position servo would be required to perform this action precisely, but for simplicity in illustration this detailed arrangement is not shown in Fig. 10.) As the input correction signal is proportional to the controlled-input sensitivity signal for a small range of operation, it can be assumed that the sensitivity signal is proportional to the input deviation signal. It follows that the controller action is to control an input adjustment rate proportional to the input deviation. In equation form, the action of the input correction rate and the input deviation may be written:

$$(CT)_{(in)} \frac{d}{dt} (D)\, q_{(in)} + (D)\, q_{(in)} = 0, \qquad (1)$$

where $(CT)_{(in)}$ represents the proportionality of the input rate and the input deviation. The solution of Eq. (1) for the input deviation is an exponential function of time with $(CT)_{(in)}$ as the characteristic time. The dash-line curve labelled average input level in Fig. 11b was constructed to represent this exponential function.

Under the assumption that within a small range of operation the controlled-system sensitivity is a linear function of the input deviation, as shown in Fig. 11d, it can be proved easily that the shape of the characteristic curve is a parabola whose vertex is at the optimum point. This means that the output deviation at any time is proportional to the square of the input deviation. For this reason the smoothed output signal is shown in Fig. 11e as proportional to the square of the corresponding value of the average input level shown in Fig. 11b. As the average-input curve is an exponential function, it can be proved easily that the smoothed output curve also is an exponential function of time, with an output characteristic-time equal to one-half the input characteristic-time.

Continuous-test-signal optimalizing controllers are generally more satisfactory than controllers of the sensitivity-signal type. One reason is that the sensitivity signal in a continuous-test-signal optimalizing controller is obtained without the use of differentiation, which reduces the effects of high-frequency interference. The continuous-test-signal controller also has the advantage of being able to generate an input correction signal independently of the speed of the input-adjustor drive. Owing to this characteristic, it is possible to produce correction signals simultaneously for several inputs without mutual interference. By using the required number of optimalizing controllers in parallel, the necessary adjustments to several inputs may be made to drive the controlled system toward the optimum point with minimum loss of time.

The feasibility of the continuous-test-signal optimalizing-controller system depends on the frequency range of tolerable interference (Fig. 8). When greater numbers of inputs are to be controlled, a wider frequency range of tolerable interference is required. For a single controlled input, the frequency range of tolerable interference should be wide enough to include both the frequency of the test signal and that required for the average input level changes of the input-adjustor drive. Controlled systems with a narrow tolerable frequency-band are difficult to control with continuous-test-signal controllers.

Output-sampling Optimalizing-controller

An output-sampling controller is operated by an output rate signal that is generated by taking differences discon-

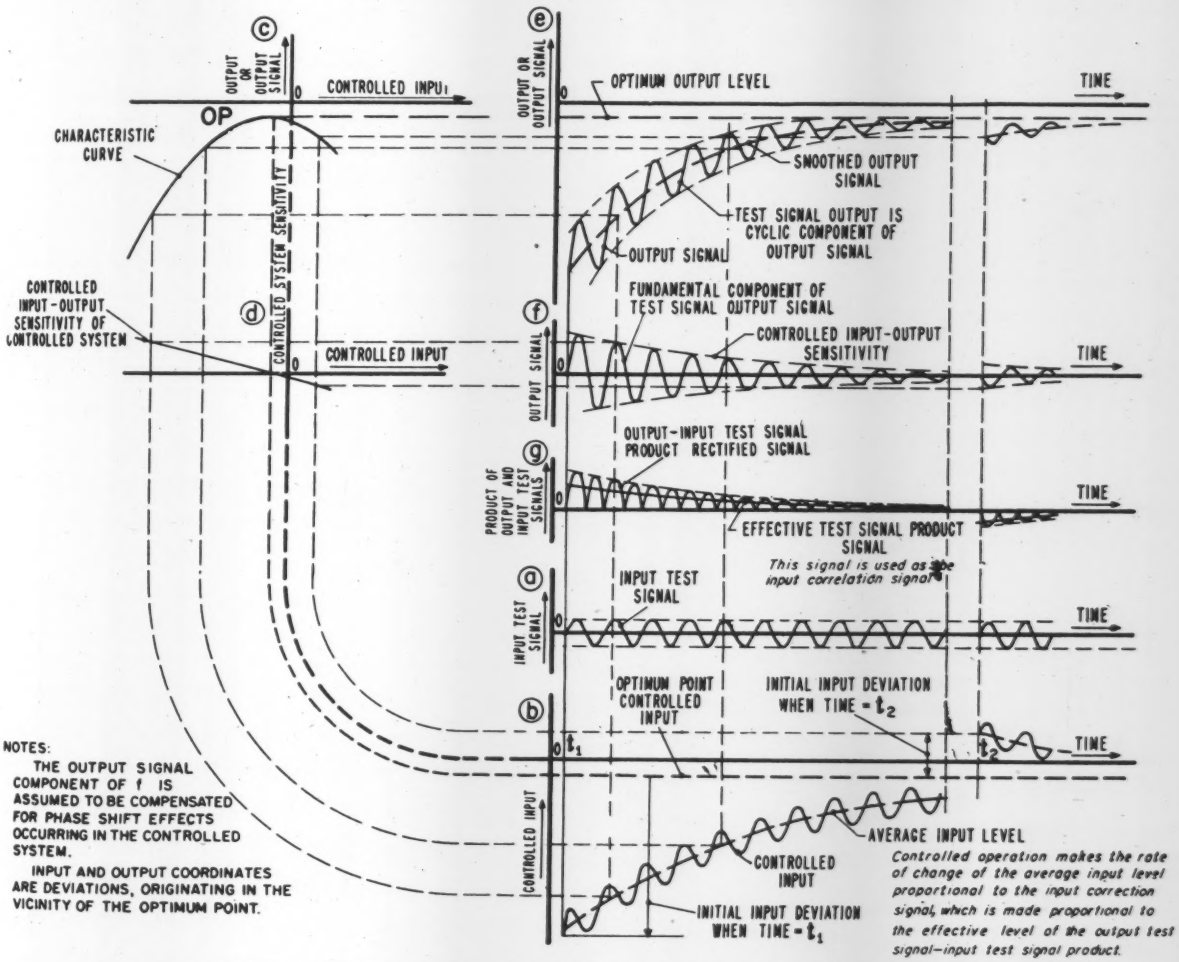

c
OUTPUT OR OUTPUT SIGNAL
CONTROLLED INPUT
OP
CHARACTERISTIC CURVE
CONTROLLED SYSTEM SENSITIVITY
CONTROLLED INPUT-OUTPUT SENSITIVITY OF CONTROLLED SYSTEM
d
CONTROLLED INPUT
e
OUTPUT OR OUTPUT SIGNAL
OPTIMUM OUTPUT LEVEL
TIME
SMOOTHED OUTPUT SIGNAL
TEST SIGNAL OUTPUT IS CYCLIC COMPONENT OF OUTPUT SIGNAL
OUTPUT SIGNAL
FUNDAMENTAL COMPONENT OF TEST SIGNAL OUTPUT SIGNAL
f
OUTPUT SIGNAL
CONTROLLED INPUT-OUTPUT SENSITIVITY
TIME
OUTPUT-INPUT TEST SIGNAL PRODUCT RECTIFIED SIGNAL
g
PRODUCT OF OUTPUT AND INPUT TEST SIGNALS
TIME
EFFECTIVE TEST SIGNAL PRODUCT SIGNAL
This signal is used as the input correlation signal
a
INPUT TEST SIGNAL
INPUT TEST SIGNAL
TIME
OPTIMUM POINT CONTROLLED INPUT
INITIAL INPUT DEVIATION WHEN TIME = t_2
b
t_1
t_2
TIME
CONTROLLED INPUT
AVERAGE INPUT LEVEL
CONTROLLED INPUT
INITIAL INPUT DEVIATION WHEN TIME = t_1
Controlled operation makes the rate of change of the average input level proportional to the input correction signal, which is made proportional to the effective level of the output test signal–input test signal product.
NOTES:
THE OUTPUT SIGNAL COMPONENT OF f IS ASSUMED TO BE COMPENSATED FOR PHASE SHIFT EFFECTS OCCURRING IN THE CONTROLLED SYSTEM.
INPUT AND OUTPUT COORDINATES ARE DEVIATIONS, ORIGINATING IN THE VICINITY OF THE OPTIMUM POINT.

Fig. 11. Typical performance diagram for an optimalizing-control system of the continuous-test-signal type.

tinuously between the average output levels for successive equal sampling periods. This output rate signal is used to produce the input correction signal, which then is used to control the hunting operation of an optimalizing system. When reversible constant input rate is used, the operation of the output-sampling optimalizing-control system is in general similar to that described in Fig. 9.

The controlled input of the output-sampling-type optimalizing-control system may be adjusted also to have a rate proportional to the sensitivity of the controlled system. The result of this type adjustment is an exponential output recovery curve similar to that shown in Fig. 11c. The detailed operating principles of the output-sampling-type controller are omitted because of space limitations.

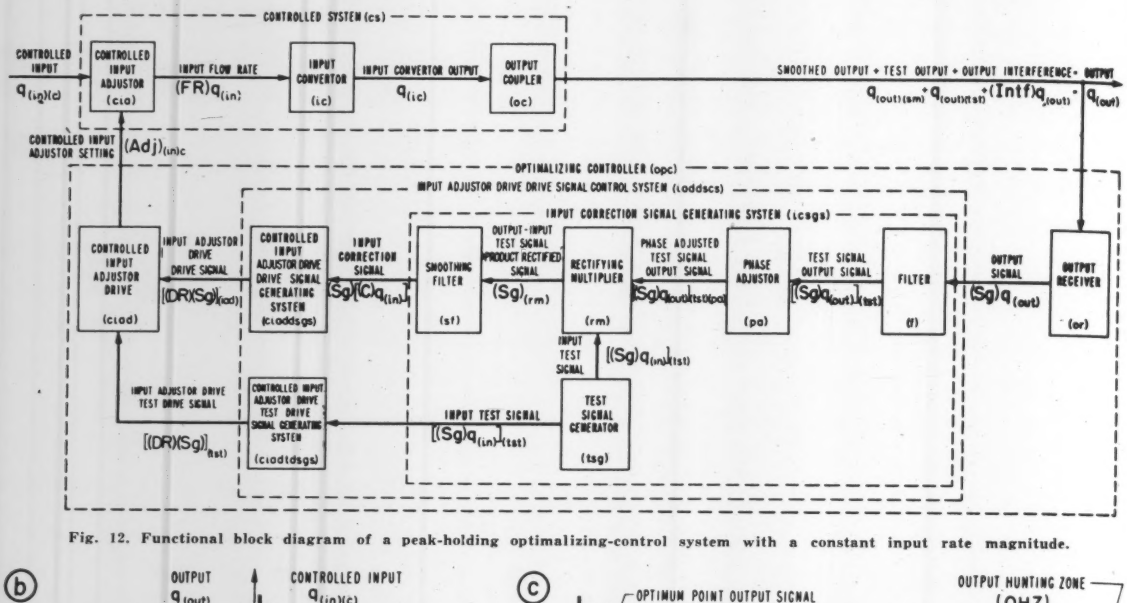

CONTROLLED SYSTEM (cs)
CONTROLLED INPUT
CONTROLLED INPUT ADJUSTOR (cia)
INPUT FLOW RATE
INPUT CONVERTOR (ic)
INPUT CONVERTOR OUTPUT
OUTPUT COUPLER (oc)
SMOOTHED OUTPUT + TEST OUTPUT + OUTPUT INTERFERENCE = OUTPUT
CONTROLLED INPUT ADJUSTOR SETTING
OPTIMALIZING CONTROLLER (opc)
INPUT ADJUSTOR DRIVE DRIVE SIGNAL CONTROL SYSTEM (ioddscs)
INPUT CORRECTION SIGNAL GENERATING SYSTEM (icsgs)
CONTROLLED INPUT ADJUSTOR DRIVE (ciad)
INPUT ADJUSTOR DRIVE DRIVE SIGNAL
CONTROLLED INPUT ADJUSTOR DRIVE DRIVE SIGNAL GENERATING SYSTEM (ciaddsgs)
INPUT CORRECTION SIGNAL
SMOOTHING FILTER (sf)
OUTPUT-INPUT TEST SIGNAL PRODUCT RECTIFIED SIGNAL
RECTIFYING MULTIPLIER (rm)
PHASE ADJUSTED TEST SIGNAL OUTPUT SIGNAL
PHASE ADJUSTOR (pa)
TEST SIGNAL OUTPUT SIGNAL
FILTER (f)
OUTPUT SIGNAL
OUTPUT RECEIVER (or)
INPUT TEST SIGNAL
TEST SIGNAL GENERATOR (tsg)
INPUT ADJUSTOR DRIVE TEST DRIVE SIGNAL
CONTROLLED INPUT ADJUSTOR DRIVE TEST DRIVE SIGNAL GENERATING SYSTEM (ciadtdsgs)
INPUT TEST SIGNAL

Fig. 12. Functional block diagram of a peak-holding optimalizing-control system with a constant input rate magnitude.

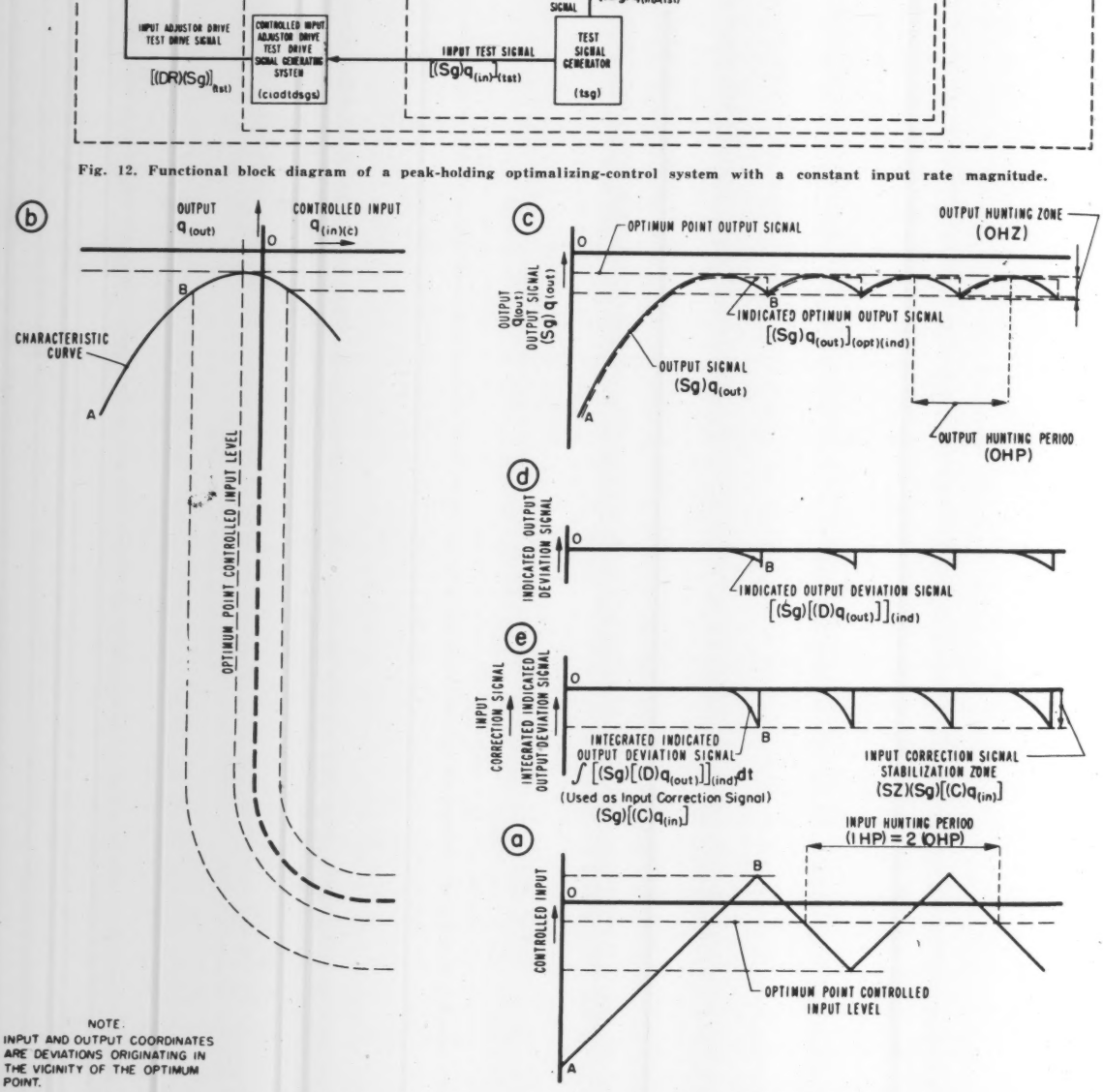


Fig. 13. Performance of an optimalizing-control system of the peak-holding type.

Peak-Holding Optimalizing-Control

Optimalizing-control systems of the peak-holding type differ from the systems described in the method used for generating the input correction signal, which has in general been a representation of the sensitivity of the controlled system. In systems of the peak-holding type, the input correction signal is based on the difference between an indicated optimum output signal (the reference quantity) and the output signal (the compared quantity).

In principle the indicated optimum output signal is equal to the output signal so long as the magnitude of this signal is increasing, but remains constant at the highest level reached when the output signal starts to decrease. The controller generates a suitable input correction signal as soon as the output signal starts to decrease, and then uses this signal to adjust the input to restore the output.

Fig. 12 is a functional block diagram of a typical optimalizing-control system of the peak-holding type. The performance characteristics are illustrated in Fig. 13. The input-adjustor drive of Fig. 12 changes the input at a constant rate. The input is shown starting at A in Fig. 13a. The input, operating through the characteristic curve (b), causes the output to have the shape illustrated in (c). So long as the output is increasing, the output reference level changes with the input. When the output passes its peak, which corresponds to the optimum output level, and starts to decrease, the peak signal is held as the *indicated optimum output signal* by the unit marked "*indicated optimum output signal generating system*" in Fig. 12. The indicated optimum output signal is supplied as one of the inputs to the *correction-signal generator*, which also receives the *smoothed output signal* from the output-signal smoothing system. The difference between the output signal (the full line in Fig. 13c) and the indicated optimum output signal (the dotted line) is the indicated output deviation signal shown in (d). Fig. 13e illustrates the integral of this deviation signal.

The integrated signal increases until a stabilization-zone limit is reached. When this limit is reached, an *input correction signal* is applied to the system which generates the input signal to the input-adjustor drive. This signal reverses the direction of the controlled-input signal. When this reversal occurs, the *input-adjustor-drive reversal signal* acts on the *signal-resetting system* to reduce the signal representing the integral of the output deviation to zero. This action is illustrated by the vertical dotted line in Fig. 13c, and by corresponding vertical lines in plots (d) and (e). As shown in Fig. 12, resetting signals are supplied both to the indicated-optimum-output-signal generating system and to the correction-signal generator. The result is that the output remains within a hunting zone (Fig. 13).

Response Delay of a Peak-Holding System

The operation of an optimalizing-control system depends primarily on the nonlinear input-output relation of the operating system. In other words, the input converter in Figs. 5, 10, or 12 must have a nonlinear input-output characteristic. In an analysis of the operation of an optimalizing system, the process is much simplified if this nonlinear input-output relation remains unchanged with time within the range of application. This means that the output of the input convertor is a function of the input flow rate only, no matter how fast the input flow rate is varying.

The input correction signal used to change the direction of the input drive also is not supposed to be a function of time. All other components between the input convertor and the drive-signal generating system for the input-adjustor drive operate in general with performance functions in which time is one parameter.

Fig. 14 shows a mathematical functional diagram of an optimalizing system consisting of an internal-combustion engine with a controller of the peak-holding type. Miniature plots show the input-output performance relationships of the nonlinear components. Other components are assumed to have linear approximations and for this reason their performances are shown by performance transformation functions. The entire system can be considered as consisting of two nonlinear systems connected by two linear groups. The linear group that contains all the linear systems associated with the controlled-system input adjustment is called the *input linear group*. The other linear group, which contains all the linear systems associated with the controlled-system output, is called the *output linear group*.

First-order linear systems like those shown in Fig. 14 are common in process-control operations. Input-output relationships of first-order systems are represented conveniently by the characteristic time of the system. In many cases, when the input function involved is of a certain simple form, the output function also can be presented in a simple form with the characteristic time as one parameter. A few examples of input functions and the corresponding first-order system responses are shown in Fig. 15.

The input-output relationships in Fig. 15 can be used to explain the operation of a peak-holding optimalizing-control system with first-order systems in the linear groups. For example, in an ideal system the output of the system (or input converter) is composed of parabolic sections (Fig. 13c). In an actual system it is reasonable to assume that the input-convertor output is basically parabolic. This signal is received by the output linear group to produce a signal suitable for generating the input correction signal.

As shown in Fig. 15, F, a parabolic input function to a

Continued on page 228

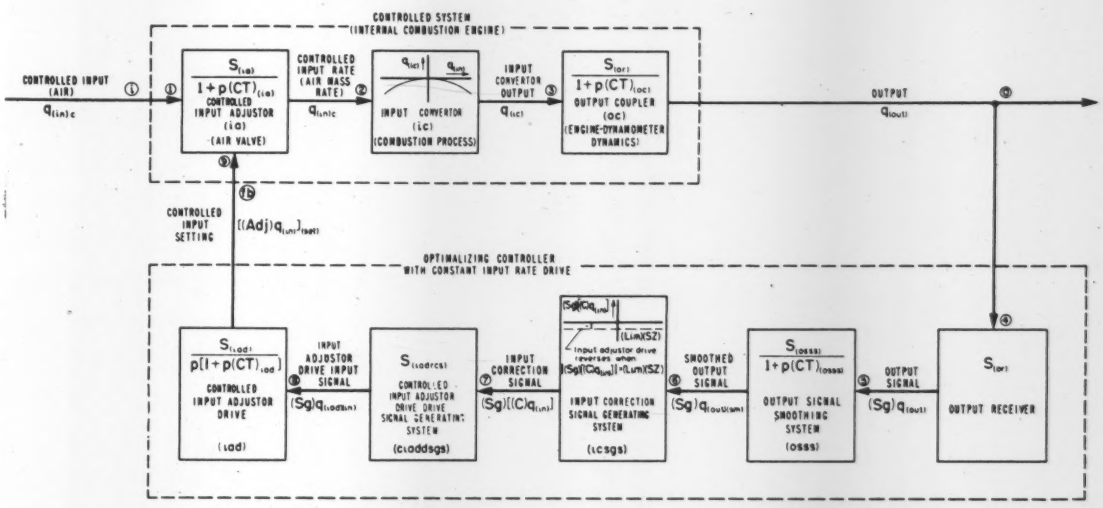
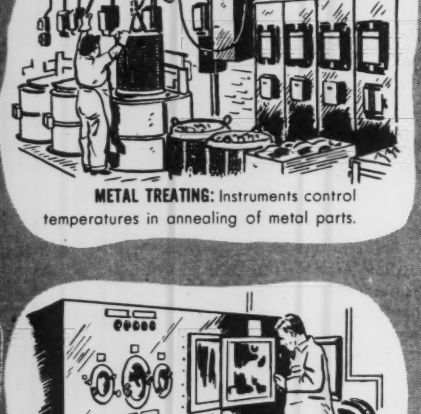
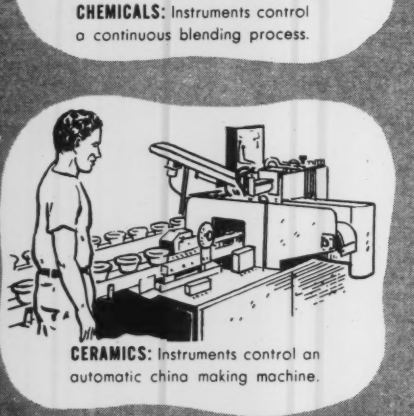

CONTROLLED SYSTEM
(INTERNAL COMBUSTION ENGINE)
CONTROLLED INPUT (AIR)
CONTROLLED INPUT ADJUSTOR (iao) (AIR VALVE)
CONTROLLED INPUT RATE (AIR MASS RATE)
INPUT CONVERTOR (ic) (COMBUSTION PROCESS)
INPUT CONVERTOR OUTPUT
OUTPUT COUPLER (oc) (ENGINE-DYNAMOMETER DYNAMICS)
OUTPUT
CONTROLLED INPUT SETTING
OPTIMALIZING CONTROLLER WITH CONSTANT INPUT RATE DRIVE
CONTROLLED INPUT ADJUSTOR DRIVE (iad)
INPUT ADJUSTOR DRIVE INPUT SIGNAL
CONTROLLED INPUT ADJUSTOR DRIVE DRIVE SIGNAL GENERATING SYSTEM (ciaddsgs)
INPUT CORRECTION SIGNAL
INPUT CORRECTION SIGNAL GENERATING SYSTEM (icsgs)
SMOOTHED OUTPUT SIGNAL
OUTPUT SIGNAL SMOOTHING SYSTEM (osss)
OUTPUT SIGNAL
OUTPUT RECEIVER

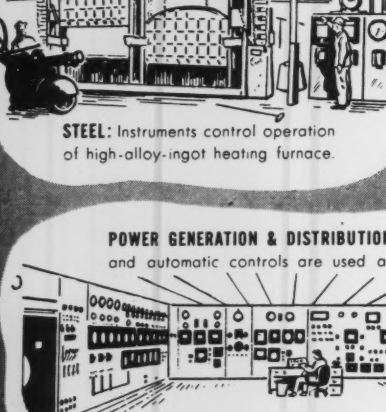
Fig. 14. Mathematical functional diagram for a peak-holding optimalizing-control system for an internal-combustion engine.



METAL TREATING: Instruments control temperatures in annealing of metal parts.



CHEMICALS: Instruments control a continuous blending process.



CERAMICS: Instruments control an automatic china making machine.

STEEL: Instruments control operation of high-alloy-ingot heating furnace.

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THE MANAGER'S PAGE

Percy V. Jones

FIRST Vice-President W. A. Wildhack reports on the expanding technical activities of ISA as follows:

Members and friends of the Society have learned through the Journal, the new President's message and the new By-Laws, of the plans for the appointment of more technical committees. The new committees will broaden and extend the scope of the technical program and activities, to encompass a larger number of specific fields of instrument application.

The majority of the early members of the Society were primarily interested in instrumentation for production processes—automatic control, recording, and analysis. Because the basic principles of measurement—and often the same instruments—are applicable to many other measurement problems, in industry or research, many other persons have found it worthwhile to attend ISA meetings and exhibits and to join the Society. These new members have brought new and varied interests and contributions. This is a healthy condition and the Society is fortunate in having a diverse membership. It is hoped that diversity in the technical programs will further add to interest, attendance, and membership growth.

The older committees are now well established and can be depended upon to arrange conference sessions of high quality. They will supply the greater part of the technical program for the September conference. However, the new committees, still being staffed, will add significant variety, even with a single session of each of the Committees. The duties of the Technical Committees as broadly defined by the Society Structure and Planning Committee are to promote activities in their respective interest fields, leading to the

(a) Preparation of approved manuscripts of papers for presentation before regional and national meetings and for publication by the Society.

(b) Preparation of recommended training programs for mechanics or others engaged in installing and maintaining instruments.

(c) Preparation of educational pro-

Continued on page 203

Single-knob Adjustment of Reset Rate and Gain

By W. I. CALDWELL†

ABSTRACT. A new circuit for a proportional plus automatic-reset controller has one adjustment which changes the proportional gain and reset rate simultaneously, without the use of mechanical linkages. The setting of this adjustment controls the stability of the system. The setting of the controller is like the tuning of a single-knob receiver which has provision for selection of different broadcast bands (types of processes).

THE purpose of this paper is to discuss the properties of a new controller circuit. With this circuit the reset rate and proportional band width are both changed by adjustment of the opening of a single needle valve. The effect of these responses on stability and the manner in which they change relative to each other are shown. No constructional details are given.

It is expected that the performance of the circuit, as it will normally be used, can be understood in terms of its automatic reset and proportional responses. The circuit has additional responses which must be taken into account in explaining its operation under some conditions. These additional responses cannot be described fully by terminology now in common use in industrial instrumentation and hence a new terminology is required.*

Definition of Proportional Gain

Responses of a controller can be described in terms of the outputs for various inputs. Responses of industrial automatic controllers have usually been described in terms of the output change produced by a sudden (step) change in input or by a constant rate of change in input. A sinusoidal input also may be used and the responses described in terms of the ratio of the amplitude of the output to that of the input for each of a large number of frequencies.** Experimentally one would apply one frequency at a time. At each frequency the input and output amplitudes would be measured after cyclic equilibrium had been established.

To simplify the discussion, assume that the controller is of the blind or non-indicating pneumatic type and that the output and input are measured in psi. With a sinusoidal input the ratio of the amplitude of the output to that of the input will be called *gain*. Fig. 1A shows a gain of two for a direct acting proportional controller and 1B, for a reverse acting proportional controller.

For any settings of a controller, the value of gain depends upon input frequency. The relationship between gain and frequency can be shown by a graph like that of Fig. 1C. In this graph the vertical scale gives values of gain and the horizontal scale, the input frequency. If the gain is two for all frequencies, this information would be shown by line *AD*.

In practice it is impossible to have a constant gain for all frequencies. At higher frequencies the gain will fall off as indicated by line *ABC*. Gain of the flat part of the curve is called proportional gain. The proportional gain of curve *ABC* is 2.

Role of Automatic Reset

On some processes, proportional response alone results in sufficiently good control. On others, to avoid cycling, the proportional gain must be set at a value so low that it makes the offsets resulting from load changes undesirably large. For these processes, automatic reset response may be added to the controller to reduce the offset to a very small value.

If automatic reset response is added to the proportional response, the gain vs frequency curve might take the

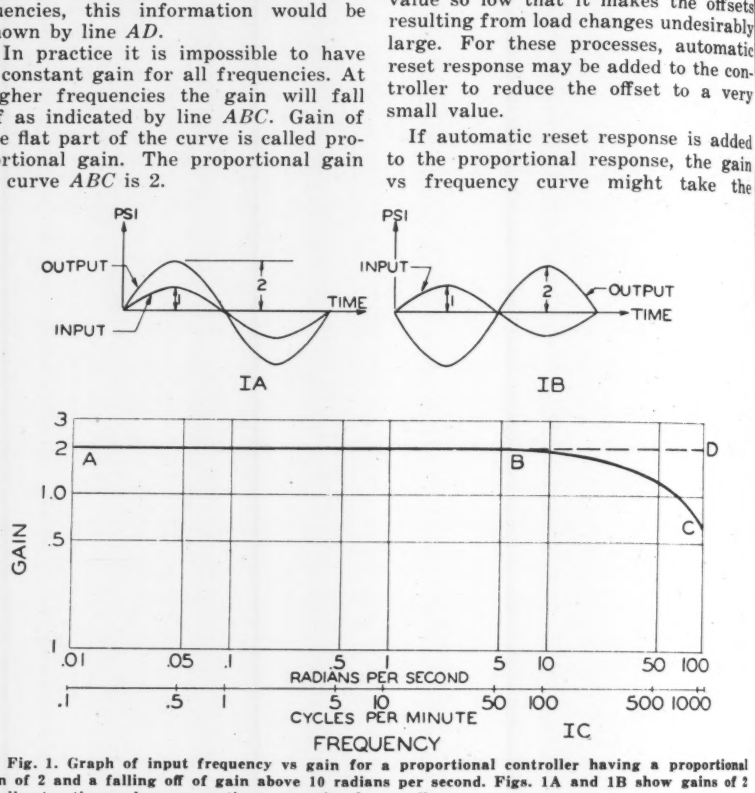


Fig. 1. Graph of input frequency vs gain for a proportional controller having a proportional gain of 2 and a falling off of gain above 10 radians per second. Figs. 1A and 1B show gains of 2 for direct acting and reverse acting proportional controllers.

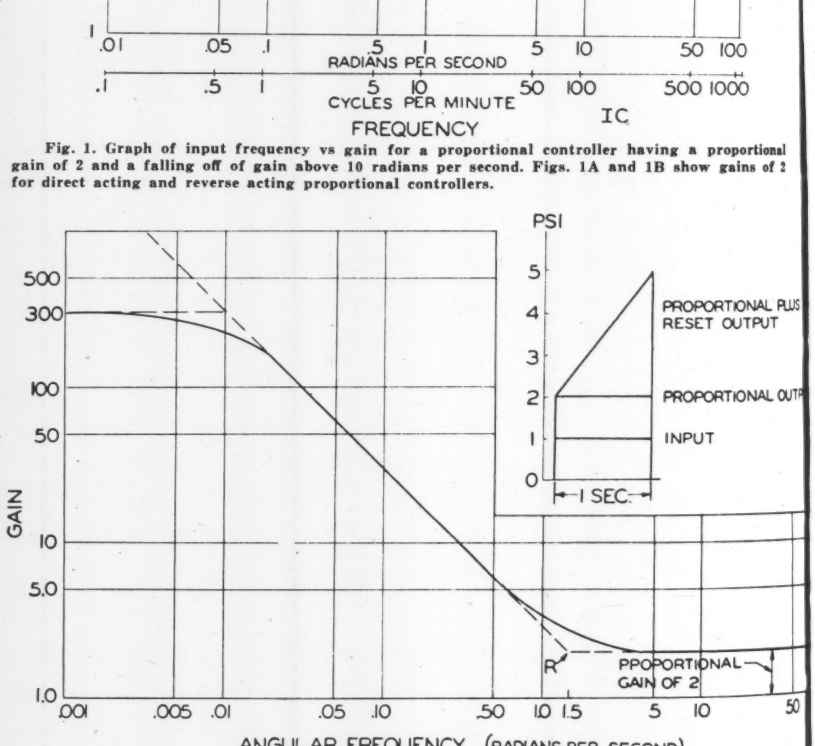


Fig. 2. Graph of gain vs input frequency for a proportional plus automatic reset controller adjusted for a proportional gain of 2 and a reset rate of 1½ repeats per second. Insert shows output for the same settings and a step input of 1 psi.

†Director of Research, Taylor Instrument Companies, Rochester, N. Y.

Presented before the Sixth Annual Conference of the Instrument Society of America, at Houston, Texas, Sept. 10-14, 1951.

*The terminology used here has been recommended by J. M. L. Janssen in "Analysis of Pneumatic Controllers" presented at the British Conference on Pneumatic Controllers.

**Discussion of phase relationships is omitted to simplify the paper.

hape of that shown in Fig. 2. It is seen that addition of automatic reset has increased the gain at low frequencies. The gain at zero frequency determines the ability of a controller to return the process variable to the set point following a load change. The higher the gain, the closer the return. The improvement in control that is obtained by adding automatic reset to proportional control in the conventional manner is at the expense of having to make settings of two adjustments.

Automatic reset and proportional responses have often been described in terms of the controller output resulting from the application of a step input. In the upper right of Fig. 2 is shown a step input of 1 psi. and the output for a proportional gain of two and a reset rate of 1½ repeats per second or 90 repeats per minute.

At the end of one second the change in output attributable to automatic reset is 1½ times that due to proportional response; hence the description of 1½ repeats per second.

The gain vs frequency curve for these settings is shown by a solid line in Fig. 2. It will be noted that this curve is asymptotic to two lines, one horizontal and the other with a slope of −45°. These lines intersect at 1.5 radians per second and a gain of two. Such intersections are called *corners*.

The corner shown is characteristic of controllers having automatic reset response and its location on the radians per second scale gives the reset rate in repeats per second. The gain value along the horizontal line is called the proportional gain. The falling off of gain that occurs with all controllers at higher frequencies is not shown.

Stability of Control with Two Responses

The stability of control with an instrument having automatic reset and proportional responses will now be considered. As the two controller adjustments are varied, the system will have varying degrees of stability or be completely unstable. Fig. 3, having proportional gain and reset rate as co-ordinates is one method of illustrating the performance of the system.

At all settings represented by points on Curve *h*, the process under consideration is on the verge of continuous cycling or hunting. Any pair of settings represented by a point to the right and above *h* will result in hunting.

As the reset rate and proportional gain settings are reduced so that the point representing them moves from Curve *h* towards Curve *cd*, the oscillations in the load recovery curve die out in fewer cycles. In other words, the control becomes more stable. A good measure of stability is based on the number of observable cycles following a given load disturbance. As the stability improves, the number of cycles decreases.

When settings corresponding to Curve *cd* are reached, the variable will return to the set point without oscillation. The recovery curves are then said to be critically damped. The resulting response curves are like the one shown for Point *B*. Settings represented by points on Curve *cd* generally would be considered too stable.

Settings with a more satisfactory degree of stability are located on the middle curve which is labeled ¼. The load change response curves for all settings represented by this curve have the same stability but differ in other respects as can be seen from the small inserts.

The most satisfactory settings, in the opinion of many people would be in the neighborhood of Point *A*. Moving to the left along this curve the reset rate becomes smaller with the result that return to the set point is slower. Moving in the opposite direction along the curve, the proportional gain becomes smaller, the amplitude becomes large and the period increases.

Stability Contours

The broken lines of Fig. 3 are called *stability contours*. Those shown are for a particular process. Other processes have been found to have similarly shaped stability contours so that the curves illustrated are roughly representative of many processes.

In conventional automatic reset plus proportional controllers, reset rate and proportional gain adjustments are independent. When they are completely independent, changing the reset rate will cause the point representing the settings to move along a horizontal line; changing the proportional gain will cause the point to move along a vertical line. Obviously, adjustment of the settings of an automatic reset plus proportional controller is more involved than adjustment of the setting of a proportional controller.

For any type of process, positions of the stability contours will depend on the constants of the equipment. Thus, given equipment under one operating condition will have a certain family of stability curves while the same equipment under different operating conditions may have a different family of curves.

This is illustrated in Fig. 4 where the stability contours are the three broken lines *cd*, ¼, and *h* for one operating condition, and the three solid lines for another. When the operating conditions change, the same degree of stability and shape of response curve can be retained only by readjusting the controller.

Suppose that when the broken lines represent the stability contours, the proportional gain and reset rate are adjusted to the values given by Point *A*. If the equipment constants then change so that the solid lines become the stability contours, the process variable will hunt because Point *A* is now in the unstable region.

To regain the same type of control, settings corresponding to Point *A′* must be found which involves changing both the proportional gain and reset rate. If only the proportional gain setting is changed without changing the reset rate, the settings will be represented by points on a vertical line passing through Point *A*.

All of these settings produce unstable control because the reset rate is too high. Similarly, a change in the reset rate without adjusting proportional gain will produce unstable control because of the high proportional gain. In the example shown, a rather large

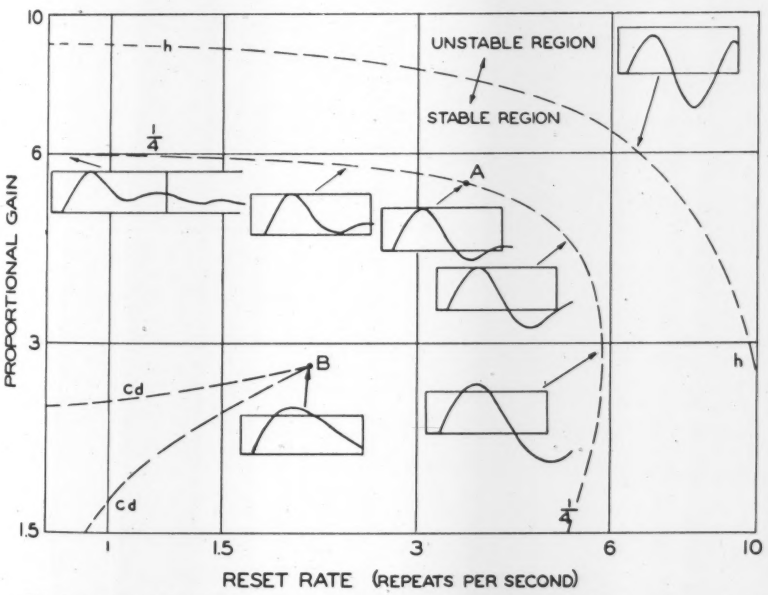


Fig. 3. Stability Contour Curves. Inserts show effect of a step load change on the controlled variable of a process computed for various settings of Proportional Gain and Reset Rate. Curve *h* gives settings that are on the verge of causing hunting. Curve *cd* is for critical damping. The middle curve is for ¼ amplitude ratio. The broken curves *h*, *cd* and ¼ are called stability contours. (Data from work to be published by Drs. G. A. Coon and G. H. Cohen).

change in process constants was assumed. This does not imply that such changes occur in all processes but they can happen.

Simpler Controller Adjustments

Is it possible to obtain most of the benefits of the addition of automatic reset response without making the setting of the controller appreciably more complicated? It would be possible to build a fixed proportional gain controller with adjustable reset rate or an adjustable proportional gain controller with fixed reset rate. Either of these possibilities would be acceptable for many processes if the right amount of the fixed quantity were used. For other processes, changes in the constants could make it impossible to return to stable control with the adjustment provided.

If the reset rate and proportional gain are linked together so that the values of both can be made small enough, it is possible to have good control at the initial setting and regain stable control after any process change by setting a single knob.

What does linking the reset rate and proportional gain together mean in terms of Fig. 4 where logarithmic scales are used? If, for example, the proportional gain and reset rate knobs are geared together so that the gain is always proportional to the reset rate, all settings will fall on a line with a slope of 45° such as AA'. This is an example of but one relationship obtained by linking the reset rate and proportional gain adjustments.

Control Circuit of One-knob Controller

The circuit which will be discussed is one in which the reset rate and proportional gain can both be varied by adjusting the value of a single resistance such as a needle valve. Consequently, the use of mechanical linkage is avoided. In a sense the reset rate and proportional gain can be said to be pneumatically linked.

This circuit, as applied to a stacked diaphragm type non-indicating controller, is shown in Fig. 5. In this figure, the set and process pressures are applied to the two middle chambers. Supply pressure is applied to the nozzle through an orifice. When the process pressure varies, the diaphragm stack will move changing the back pressure in the orifice-nozzle line.

Suppose the change in input pressure is in the direction to make the back pressure increase. This will cause the output pressure from the Booster Relay to increase. All of this increase in pressure will be applied to the lower diaphragm chamber. Part of the increased pressure will be applied to the upper chamber by the pressure divider composed of resistances r_1 and r_2.

If the needle valve r_1 is closed, no pressure change will act on the upper chamber and the proportional gain will be at its lowest value. If the needle valve is wide open, the pressure applied to the two chambers will be nearly equal and the proportional gain will be high. The increased pressure in the upper chamber will cause flow into the capacity tank.

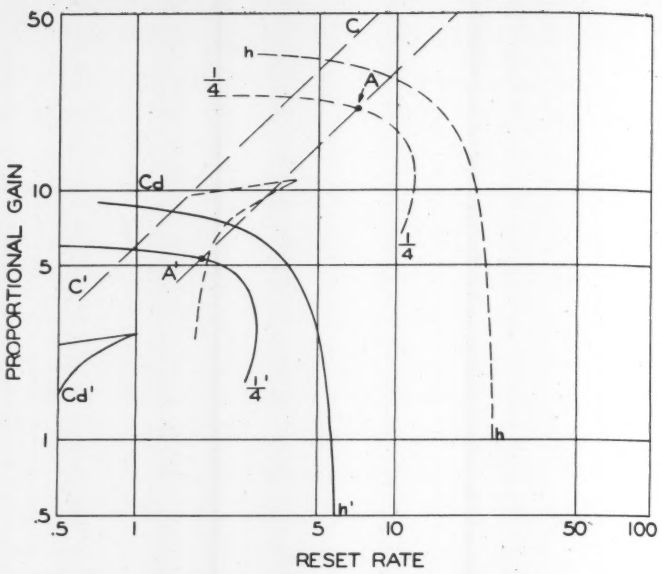


Fig. 4. Stability contours before and after change in equipment constants.

As the pressure in the tank increases, the pressure in the upper chamber will also increase. This will result in reset action. The reset rate depends on the sum of the two resistances. Consequently, the resistance to flow of needle valve r_1 will effect both the reset rate and the proportional gain.

Gain-Frequency Curves for the Circuit

A more complete description of the responses of the circuit will be given by use of gain vs frequency curves. Before looking at these, let us refer again to Fig. 2 which shows the gain-frequency curve for a proportional plus reset controller. In this figure, the zero frequency gain was assumed to be 300. As the frequency increases, the gain decreases until the proportional gain of 2 is reached. The reset rate which is 1.5 repeats per second, is given by the location of the corner R on the angular frequency scale. In this diagram there is only one such corner.

Several gain-frequency curves for the circuit under discussion are shown in Fig. 6. This family of curves was computed for a given value of the fixed resistance r_2 and four different values of the variable resistance r_1. It will be observed that some of these curves have two corners similar to corner R in Fig 2. Examples of this are C and D. The corners on Curve ACB are always present and are like the corner R of Fig. 2 in all respects.

At frequencies lower than those for ACB the gain climbs rapidly to a high value. At frequencies immediately higher the gain is constant for an appreciable range of frequencies. This gain will be called the proportional gain and the angular frequency value of each corner on ACD will be the reset rate in repeats per unit of time. The responses corresponding to the D corners are unnamed.

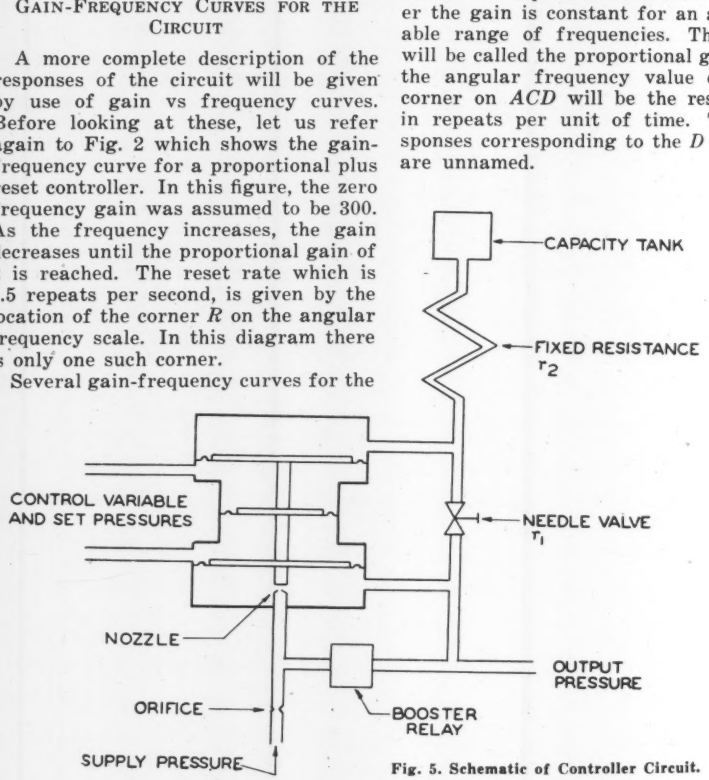


Fig. 5. Schematic of Controller Circuit.

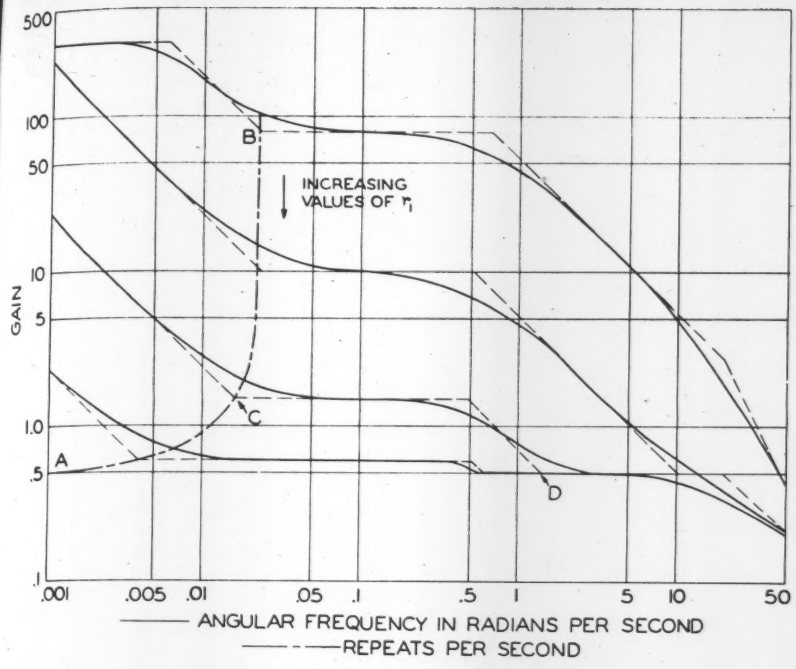


Fig. 6. Solid lines are curves of gain vs frequency in radians per second corresponding to a fixed value of r_2 and various values of r_1. The Curve *AB* shows the corresponding relationship between proportional gain and reset rate in repeats per second.

Referring to Fig. 6, a larger value of fixed resistance shifts the curves to the left, while a smaller value shifts the curves to the right. Referring to Curve *ACB* it is seen that as the resistance of r_1 increases, both the proportional gain and reset rate decrease. This decrease of both proportional gain and reset rate increases the stability of control as was pointed out in the discussion of Fig. 3.

Effects of Instrument Design on Curves

Certain details of the gain-frequency curves will be determined by instrument design. For example in constructing Fig. 6 the value of minimum proportional gain was assumed to be ½. This value depends upon the ratio of effective areas of the diaphragms in the instrument. The assumed value of zero frequency gain was 300. This value is attainable with a minimum proportional gain of ½.

It will be noticed that the gain values fall below the proportional gain, in Fig. 6, at corner frequencies of about 0.5 radians per second. The relationship between this frequency and the maximum value of reset rate primarily depends on the ratio of capacities of the capacity tank and the upper diaphragm chamber.

By reference to Fig. 6 it may be seen that gain-frequency curves can be approximated by straight lines. This approximation is often used because of the simplicity of construction and because the corner frequencies can be read off directly.

An instrument having this circuit was used to control flow in an experimental set up. In these tests two different values of fixed resistance were used. Load change recovery curves were recorded for different settings of the needle valve with each fixed resistance. The results are shown in Fig. 7.

The solid line *DD* shows the relationship between proportional gain and reset rate for one of the fixed resistances. The small inserts are tracings of the load change recovery curves. These recovery curves show the increase in stability resulting from increasing the resistance of the needle valve. Continuous cycling was observed at the setting, Proportional Gain, = 1 + and Reset Rate = 0.8 repeats per second (= 48 repeats per minute).

These settings agree with those of a conventional two-knob proportional plus reset rate controller. The straight line approximation of the gain frequency curve for these settings is shown by the broken line *D'D'*. The frequency of continuous cycling was 36 per minute which is equal to 3.8 radians per second. This frequency is located on *D'D'* by a cross.

Effects of Larger Fixed Resistances

It is interesting to see what happens to the load response curves when a much larger value of fixed resistance is used. Curve *B* shows the relationship between proportional gain and reset rate when the fixed resistance is 70 times as large as used for Curve *D*. With this larger value of fixed resistance, the needle valve setting again adjusts the stability of control.

It is noticed that for a given stability, the use of the larger fixed resistance has resulted in an increase in the values of proportional gain and a large decrease in the values of reset rate. For example, in the case of continuous cycling the proportional gain is increased from 1 to 11 and the reset rate is decreased from 0.85 to 0.011 repeats per second (51 to 0.66 repeats per minute).

The reason for these changes in readings can be seen by reference to *B'B'*, the straight line approximation for the gain-frequency curve. It shows the falling off in gain at higher frequencies that was discussed in connection with Fig. 6. The observed frequency of continuous cycling is 30 per minute or 3.2 radians per second.

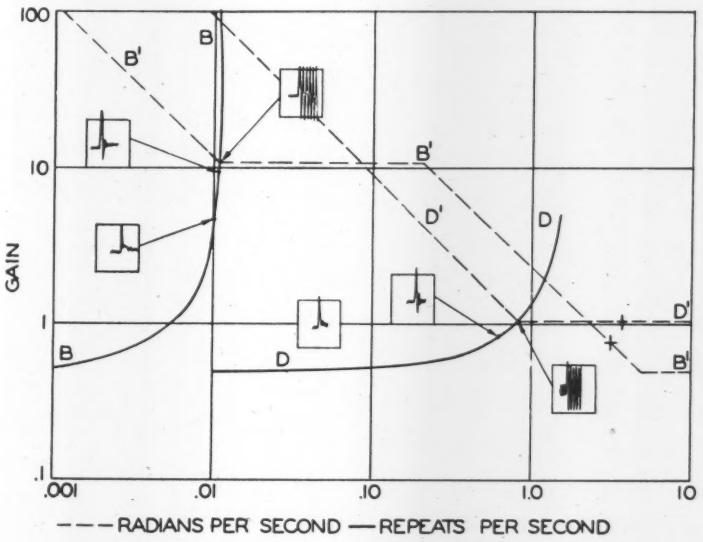


Fig. 7. The broken curves show the straight line approximations of gain vs frequency for two sets of values of r_1 and r_2. The solid lines show the corresponding relationships between proportional gain and reset rate. The inserts are the load change responses of a flow process for the settings indicated.

At this frequency the gain, shown by Curve $B'B'$ is about 0.8. This value of gain is appreciably less than the proportional gain (=11). Since the gain at the frequency of cycling is not the proportional gain, the value of the proportional gain does not have its usual significance. For the same reason it can be shown that reset rate does not have its usual significance.

If one were to pick out the two most significant figures for this process and controller setting, they would be a gain of ½ and a frequency of 5 radians per second. This "corner" has not been named. In the neighborhood of this corner the gain vs frequency curve has the same shape that it has in the neighborhood of the reset rate-proportional gain corner.

For processes where the frequency of cycling is lower, the proportional gain and reset rate values given by Curve BB have essentially their usual significance.

As far as we have been able to determine, stable control can be obtained with any value of fixed resistance for any process that can be controlled by an automatic reset plus proportional controller having the same minimum proportional gain.

Conclusions

A circuit has been discussed in which the reset rate and proportional gain are pneumatically linked in such a way that both can be decreased simultaneously by a single setting knob. This knob, which adjusts the stability of the control, makes setting of the instrument essentially as simple as setting a proportional-only controller. By use of suitable fixed resistances, good control can be obtained for a wide range of types of processes including those requiring high reset rate and those requiring high values of gain.

Instrumentation of Tire Curing Presses

By R. N. WILSON* and W. G. BARGER**

ABSTRACT. Rising labor and material costs focus attention on efficiency and reliability of modern instruments to produce uniform products at lower cost. Instrumentation applied to the tire curing operation of the rubber industry produces a better product—which gives the motoring public many times the value received a decade ago.

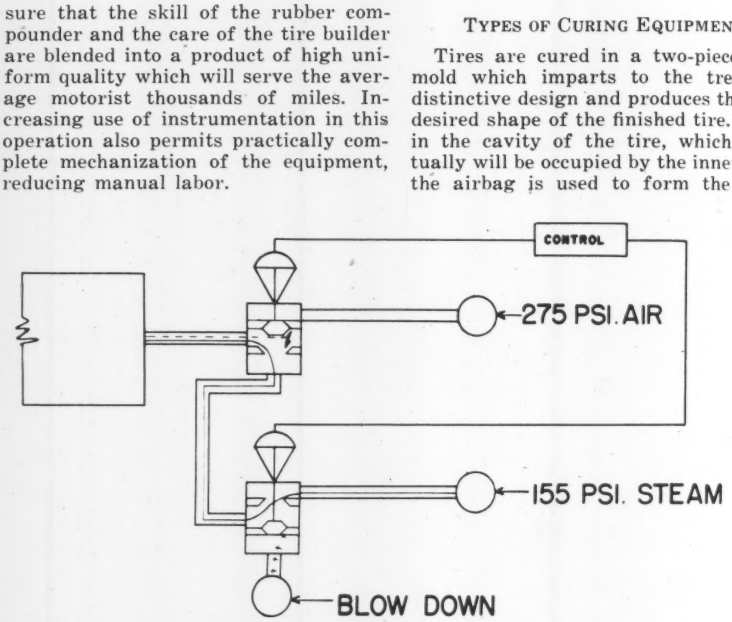
IN THE manufacture of automobile and truck tires are numerous examples of modern instrumentation methods to control the many varied steps by which the raw materials are processed into a completed tire. Contrary to popular belief, many sub-assemblies are required for the final building operation of a tire, which is then shaped and cured in a mold. Because of the elastic nature of these sub-assemblies, extreme care must be exercised to insure a quality product. Modern instruments are becoming increasingly important in improving tire quality and increasing tire life in service.

Briefly, a tire is made by building up to a desired thickness, over a steel drum, diagonally cut plies of rubber coated cord. Ultimate service dictates the number of plies in a tire carcass. Whereas an ordinary passenger tire requires but four or six plies, heavy-duty tires, designed for logging or some similar "off the road" service, may require up to twenty plies. Wire beads are inserted at the edges between plies and a heavy strip of uncured rubber, for the tread, is applied, and the "green" tire, in the shape of an open end cylinder similar to a steel barrel without heads is removed. It is then formed over a hollow, thick walled rubber core, known as an "airbag", into the familiar shape, ready for curing.

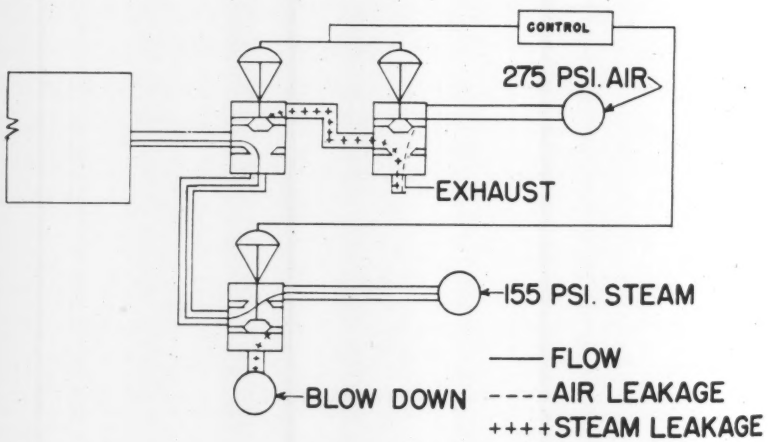
In the curing operation, where the component tire parts are "welded" into a homogeneous mass, instruments assure that the skill of the rubber compounder and the care of the tire builder are blended into a product of high uniform quality which will serve the average motorist thousands of miles. Increasing use of instrumentation in this operation also permits practically complete mechanization of the equipment, reducing manual labor.

Types of Curing Equipment

Tires are cured in a two-piece steel mold which imparts to the tread its distinctive design and produces the final desired shape of the finished tire. Within the cavity of the tire, which eventually will be occupied by the inner tube, the airbag is used to form the inner



NORMAL 2-VALVE HOOK-UP (STEAM ON)



RELIEF-VALVE HOOK-UP (STEAM ON)

*Instrument Supervisor, and **Senior Staff Engineer, The Kelly-Springfield Tire Co., Cumberland, Md.

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Statements and opinions expressed herein are those of the authors, and not necessarily those of the Society.

surface. Steam is admitted in the airbag to effect the cure in the carcass portion of the tire. Airbag walls are over ½-inch thick at the thinnest portion, and are contoured to the inner surface of the tire. In the bead area, the airbag actually molds the inner surface of the tire to desired shape.

Cure is effected by the regulated application of steam heat for a definite interval of time. There are two principal ways the heat is applied. In one method, steel mold halves are mounted on a steam-heated platen in which heat for curing is conducted from the platen through the mold to the tire. The second method employs live steam to surround the curing mold, which is mounted in an individual "dome" press or stacked on a hydraulic ram in a vertical heater or autoclave.

All three types of curing equipment just mentioned, the platen press, the individual steam dome press, and the autoclave or "pot heater", are in use in our plant, each for a specific reason. Our line has over 500 different types and sizes of tires, some of which are large volume items, whereas others are produced only in small quantities. The pot heater, while less efficient, (requiring longer cycle time) provides extreme flexibility in that a mold can be inserted or removed from the curing cycle with little lost time.

Individual dome type presses, where live steam surrounds the mold, are used for large volume runs on large size tires because of their greater efficiency over the pot heaters (that is, more cures per mold per unit of time). Platen presses are most efficient and are used on large volume runs on small passenger tires.

Platen presses are not well suited to curing the large heavy-duty tires because of unequal heat distribution in the large mold mass. It is with these latter two types of individual automatic presses that we are concerned in this paper. Without modern instrumentation, efficient and economical tire production would not be possible.

The Curing Cycle

Curing cycles vary with different types of tire construction, being so calculated as to provide uniformity of cure throughout the tire. When a new type of tire is first put into production, sample tires are built with thermocouples embedded into the tire itself, between the various plies and at the bead and the tread. Observations taken during the test cures permit the determination of the actual cure of each component part and the calculation of the best cure, as to time and temperatu e, for that particular tire in the particular type of curing equipment in which the tests are made.

Autoclaves or "pot heaters", steam dome presses, and platen presses all have different curing characteristics for the same tire. So critical is the curing process that deviation of the control temperature of more than one degree plus or minus, during the curing cycle can cause a serious under or over cure, resulting in defective tires.

In general, for both types of curing presses, the curing cycle consists of the following steps:

Close Press
Admit Steam to Airbag
Admit Curing Steam Around Mold (except platen press as we shall see later)
Turn Off Steam to Airbag
Admit High Pressure Air to Airbag
Turn Off Air to Airbag
Turn Off Curing Steam
Press Opens

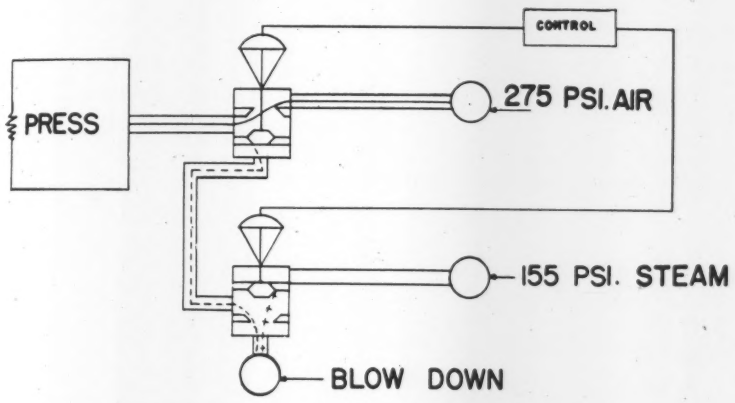
Typical Cure—Steam Dome Press

A typical cure for a steam dome type of press begins with 200 psi. steam being admitted to the airbag. This is dead end service, pressure controlled, and the condensate is not trapped off. After a predetermined time (3 to 15 minutes), steam is admitted to the dome portion surrounding the outside of the mold. This curing steam is regulated by temperature control, as are the condensate dumps. Steam to the airbag is turned off, and pressure is maintained by backing it up with 220 psi. air.

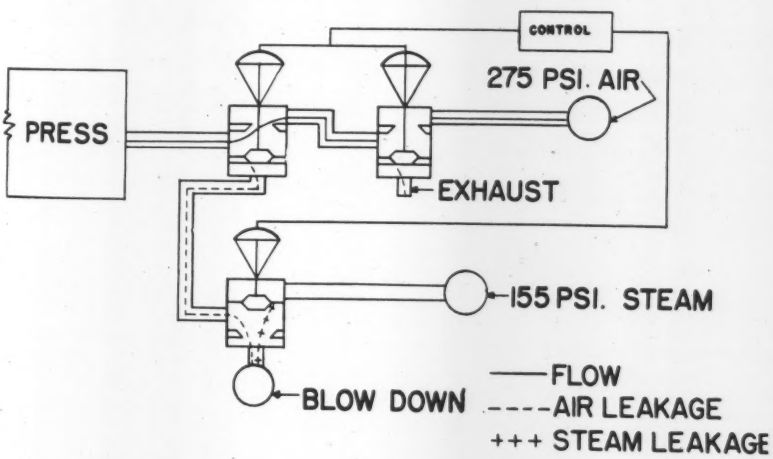
Since the higher airbag pressures are necessary to mold the tire to the mold contour, some means must be provided to maintain the pressure, but reduce the temperature. If the temperature incident with the high molding pressure were continued for the complete length of the cure, particularly in the case of large truck tires which are cured for more than two hours, over-cure of the tire carcass would occur, and an unserviceable product would result. To equalize the curing rate of the interior of the tire, the full line pressure of 200 psi. steam (±5 psi.) is used for a predetermined length of time. Use of air as a backup continues the high pressure and equalizes the rate of cure.

Upon completion of cure—again a predetermined time—the steam to the chest and air to the bag is turned off and the press opens. Operation sequence is accomplished by a cycle controller with variable time range with automatic reset, employing variable cams to permit variation in interval setting. It also controls the on and off three-way valves serving the airbag steam and air lines. Steam chest and condensate are temperature controlled by direct and reverse acting valves, respectively, to which control air is supplied in series with, and after, the curing cycle controller. The cycle controller causes opening of the press at the end of each cure.

Electrical pressure switches, on the



NORMAL 2-VALVE HOOK-UP (AIR ON)



RELIEF-VALVE HOOK-UP (AIR ON)

airbag lines and on the steam-to-chest lines, maintain an open circuit on the press motors, until pressure is released, providing for additional safety.

Platen Press Operation

Platen press operation varies slightly from that described above. Sequence of operations is determined by a cycle controller: first, admitting 200 psi. steam to the bag; then, air to the bag. In some tire sizes, to prolong airbag life and for a more rapid cure, 100 psi. steam can be used instead of air to maintain backup pressure and at the same time maintain a satisfactorily equalized cure throughout the tire.

Since the molds are mounted on steam heated platens which are maintained at constant temperature by a separate temperature controller, no on and off control for this service is necessary. Platen condensate is removed by a cycle dump, operated by a separate cycle timer, so that a purging of the entire platen is obtained each time the condensate dumps. Pressure switches are needed only on the airbag lines to assure safe operation of the platen press.

Problem of Air Leakage Into Airbag Steam Line

The very nature of the curing cycle introduces a serious problem of high pressure air leakage into airbag steam line. Presses were originally equipped with a three-way air valve and a three-way steam valve so arranged in series that the air valve controlled both services to the press. Leakage from higher pressure air to lower pressure steam line across the valve seat caused defective cures.

This problem was overcome by installing an additional three-way valve on the air line in series with the three-way valve formerly controlling both services, so that air leakage is vented to the atmosphere and does not back up into the steam line or blowdown line.

Problem of "Coffee Grounds" in Airbags

One other problem peculiar to the tire curing process can also be attributed to the airbags. Under repeated cures and handling, the inner wall of the airbag oxidizes and flakes off to form a fine sediment closely resembling, and for want of a better name, often called "coffee grounds". Venting the bag to the atmosphere at the end of each cure forced these grounds into the lines between the bag and the valve, and of course, into the control lines to the pressure recorder and safety pressure switches, destroying the effectiveness of the Bourdon tubes and the switch bellows.

This was eliminated by installing a special self-cleaning filter at the "tee" connection to the recorder and a switch consisting of brass wool (scouring pads) between perforated stainless steel disks, inserted between reducing bushings in a one-inch pipe coupling. The self-cleaning feature is possible because, as the airbag air is completely exhausted to atmosphere, evacuation of air from the Bourdon and pressure switch bellows blows back across the filter, knocking off the build-up. Since this cleaning action occurs each cure, the grounds do not build up and bake in the filter or control elements.

Conclusions

As can be seen from the foregoing, instrumentation has produced an operation which is entirely automatic from the time the operator places the uncured tire in the mold and pushes a button until the press opens, releasing the cured tire. Such modern equipment under the watchful eye of automatic controls enables the rubber industry to mass produce a uniform, high quality product at low cost to the consumer and with less fatigue to the worker.

Second Steel Instrumentation Conference

The Instrument Society of America, Pittsburgh Section, will hold its Second Conference on Instrumentation for the Iron and Steel Industry, April 3rd and 4th, 1952 at the Roosevelt Hotel.

The following papers will be presented and discussed:

"Ultrasonic Inspection of Steel Products"—H. E. Volkenberg, Sperry Products Co.

"Facilities for Instrument Maintenance and Training of Instrument Personnel in Steel Plants"—J. H. Cuthbert, Supervisor Instruments and Controls, United States Steel Co.

"Status of Bath Temperature Pyrometry in Open Hearth Furnaces"—Reports by Lester H. Veiock, Instrument Engineer, Heppenstall Co. and F. S. Swaney, Combustion Engineer, Jones & Laughlin Steel Corp.

"Operation Controls for the New Open Hearth Furnace at Jones & Laughlin Steel Corp."—R. A. Lambert, Supt. Steam Efficiency and Combustion, Jones & Laughlin Steel Corp.

"Instrumentation Factors Affecting Production in Soaking Pits"—F. R. Pullen, Fuel Engineer, Bethlehem Steel Co.

"Inspection of Forgings and Castings"—Paul J. Sherwin, Chief Inspector, Homestead Works, United States Steel Co.

"Radiographic Methods of Inspection"—Speaker to be announced.

"Instrument Application to Treatment, Use and Disposal of Waters in Steel Industry"—E. C. Eger & C. F. Hauck, Hall Labs., Inc.

"Instrumentation for River Pollution Problems"—Richard D. Hoak, Mellon Institute for Industrial Research.

"Design and Use of Equipment in Air Pollution Measurements"—W. C. L. Hemeon, Engineering Director, Industrial Hygiene Foundation of America, Inc.

"Instrumentation Factors Affecting Production in Slab Heating Furnaces"—C. M. Yaeger, Chief Combustion Engineer, Otis Works, Jones & Laughlin Steel Corp.

"Measurement of Blast Furnace In-Wall Temperatures"—S. J. Paisley, Instrument Technician, National Tube Co.

"Coke Oven Gas Booster Control and its Complications at One Plant"—Frank Revell, Instrument Engineer, Koppers Co.

Headquarters of the ISA Second Conference, Instrumentation in the Iron and Steel Industry will be the Roosevelt Hotel. Room reservations for the meeting should be made direct by those who plan to attend. *For additional information write W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh, Penna.*

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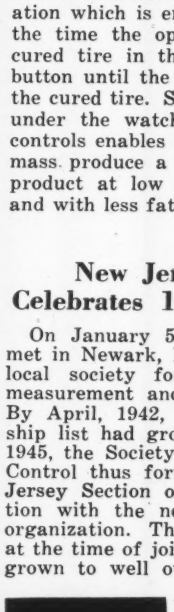
New Jersey Section Celebrates 10th Anniversary

On January 5, 1942, nineteen men met in Newark, N. J. and organized a local society for men interested in measurement and control in industry. By April, 1942, the charter membership list had grown to forty-eight. In 1945, the Society of Measurement and Control thus formed became the New Jersey Section of the ISA by affiliation with the newly formed national organization. The membership of 100 at the time of joining the ISA has now grown to well over 300.



H. F. MOORE

On January 8, 1952, a short ceremony was held at the opening of the regular meeting to mark in passing this tenth anniversary. Mr. S. M. Laird acted as Honors Chairman. He reviewed briefly the reasons why the Society was formed, some of the highlights of its growth, and presented a scroll to one of the charter members of the group, Mr. Harry F. Moore. He was chosen to be thus honored as an outstanding member of this group, typical of the many whose time and effort contributed to building the New Jersey Section to its present status.

New Jersey is not only one of the largest but one of the most active Sections nationally, having at the present time twenty-six men serving on thirty-four ISA committees plus service on the Executive Board by National Treasurer George R. Feeley.

MANAGER'S PAGE

Continued from page 195

grams for the benefit of the members of the Society and others interested in instrumentation.

(d) Conduct of investigation work required to carry out any of the above objectives.

(e) Conduct of research work on problems of a fundamental nature of general interest to members of the Society.

(f) Preparation of technical reports covering investigative or research work.

In arranging the technical program for the 1952 Conference, short contributed papers are solicited from all members. Within the limits of program time, any member may be allowed ten to fifteen minutes to present his contribution. Only the title and an abstract of 200 words or less need be submitted for these papers and they can be submitted up to July 1. However, it is hoped that authors will submit manuscripts also, so that their papers may be considered for publication in the *Journal* of the ISA. Longer papers, to be considered by the Editorial Committee, should be submitted at once, to allow time for editorial review and preprinting.

Many ISA members making interesting and significant developments, may not be able to attend the conferences, but they may, and are urged to, submit papers to the Technical Committees for editorial consideration for publication in the *Journal* of the ISA. Members should remind their associates of these opportunities for professional recognition and advancement, and Section officers should urge that outstanding talks at Section meetings be submitted for publication, presentation at the National Conference, or both.

Regrouping of Technical Committees

In order to achieve an equitable distribution of the administrative workload in the Society, First Vice-President Wildhack and Technical Vice-President Boyd have agreed to divide responsibility for coordination of Technical Committees. Committees and Chairmen reporting to Messrs. Wildhack and Boyd are as listed below.

Vice-President D. M. Boyd, Jr., Universal Oil Products, 310 S. Michigan Blvd., Chicago 4, Ill.

Instrument Operation and Maintenance—J. Johnson, Jr., E. I. DuPont de Nemours & Co., Wilmington 98, Del.

Instrumentation for Inspection and Gaging—W. A. MacCreahan, Empire Box Corp., Garfield, New Jersey

Instrumentation for Production Processes—W. H. Brand, c/o Carbide & Carbon Chemical Co., Union Carbide & Carbon Corp., P. O. Box P, Oak Ridge, Tenn.

Recommended Practices—A. V. Novak, 2256 Westway, Orange, Texas

Analysis Instrumentation—Dr. A. H. Peterson, Mellon Institute, 5th Ave., Pgh. 13, Pa.

Vice-President W. A. Wildhack, Natl. Bureau of Standards, Washington 25, D. C.

Technical Program*

Instrumentation for Transportation—F. H. Catlin, 544 W. 31st St., Erie, Pa.

Medical Instrumentation—Dr. H. J. Morowitz, Nat'l. Bureau of Standards, Washington, D. C.

Meteorological Instrumentation—Christos Harmantas, U. S. Weather Bureau, Washington 25, D. C.

Radiation Instrumentation*

Geophysical Instrumentation—Dr. D. S. Muzzey, Naval Ordnance Lab., White Oaks, Md.

Physical Properties Measurement*

Research & Development*

Testing Instrumentation—D. C. Little, Medical Research Laboratory, Fort Knox, Ky.

*Chairman awaiting appointment

Section officers are urged to write to the Vice-Presidents or the Committee Chairmen with their recommendations and suggestions for appointment of Committee members from their Sections.

Joseph A. Pellettere

The National ISA and the Pittsburgh Section lost a valued member on January 14, 1952 through the death of Joseph Pellettere.

Mr. Pellettere, had almost thirty years experience in the instrument field since his graduation in 1922 from Rice Institute in Houston, Texas with a B. S. in Chemical Engineering.

In addition to his work as Chief Instrument Engineer of the Gulf Oil Corporation, Mr. Pellettere was a faculty member at the University of Pittsburgh where recently he taught a popular graduate course entitled, "Process Control Instrumentation."

He was well known throughout the country, having authored numerous technical publications, and delivered many speeches before technical societies.

Mr. Pellettere was also a member of the American Society of Mechanical Engineers and the American Petroleum Institute.

"Principles of Automatic Control"

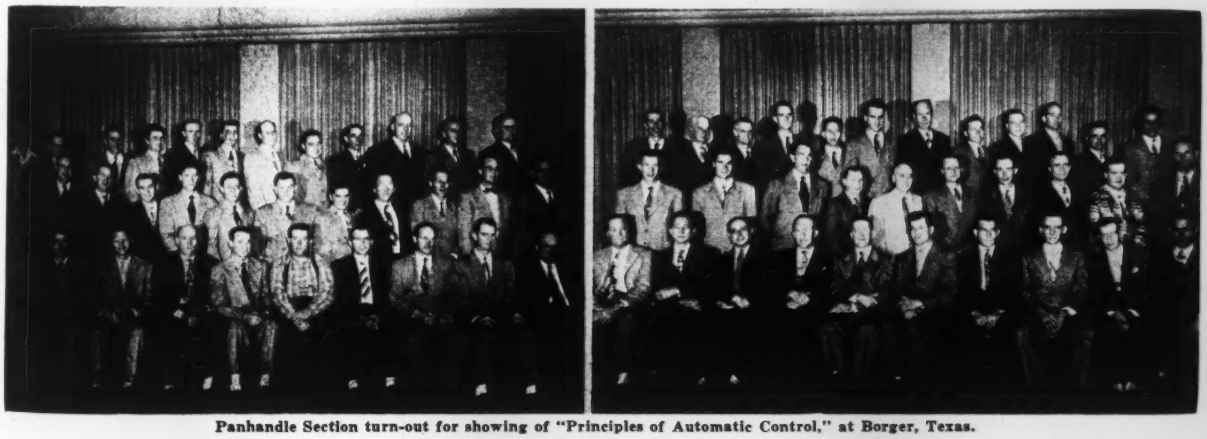
The accompanying composite picture shows members and guests who attended the November meeting of the Panhandle Section for a showing of the ISA film, "Principles of Automatic Control."

First shown during the Fifth National Instrument Conference at Buffalo in September 1950, the film has since been loaned for 230 showings to ISA Sections, other Societies, various engineering groups, educational institutions, and companies. The value of this film is attested by the continuing demand for loan showings as well as by sales of prints to companies. By mid-January 1952 the three copies available for loan distribution were solidly booked for 130 showings on a tight schedule which had no open dates until June 1952, and 13 copies had been sold or on order. Of that number, 9 were sold in the U. S., and one each in England, South Africa, Netherlands, and Netherlands West Indies.

Inquiries received from other companies abroad further emphasize the universal acceptance of and need for the information in this fine film and only the difficulty in obtaining United States funds for its purchase has held foreign orders to the four above noted.

Ken Goldring, Film Chairman of the Sarnia Section agreed to handle bookings for Canadian companies and Sections that had requested showings of the film. One print, therefore, has been sent to Canada where it will remain for approximately two months.

We feel that all ISA members should see "Principles of Automatic Control" several times and Section Program Chairmen are strongly urged to plan to fit this film into their fall programs by making reservations now.



Panhandle Section turn-out for showing of "Principles of Automatic Control," at Borger, Texas.

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA
1319 *Allegheny Ave., Pittsburgh 33, Pa.*

SUPERVISING ENGINEER. To head project for research and development in pneumatic and electrical instrumentation. Mechanical Engineer with electro-mechanical background preferred. Should have ten years of practical experience in the field indicated. Excellent opportunity with large instrument manufacturer for well qualified man. Location Pennsylvania. Box 622

SENIOR ENGINEERS. To conduct individual operations of an overall project for research and development in pneumatic and electrical instrumentation. Mechanical or Electrical Engineers with practical electro-mechanical background of five years. Age limit 35 years. Location Pennsylvania. Box 623

JUNIOR ENGINEERS. To work under direction on project for research and development in pneumatic and electrical instrumentation. May be recent engineering graduates with one or two years experience in development work. Location Pennsylvania. Box 624

INSTRUMENT ENGINEERS. Graduate Mechanical, Electrical, or Chemical, with several years process instrumentation experience for position as Contact Engineer handling design, purchasing, and engineering on prefabricated control panels. Positions are permanent offering unusual opportunity for advancement. Midwest location. Box 625

ENGINEERS. Experienced in thermodynamics, aerodynamics, high speed machinery for work on industrial gas turbines. Location Central New York State. Box 626

AERONAUTICAL INSTRUMENTATION ENGINEERS. One of the nation's leading university-affiliated research laboratories has several openings in the instrumentation section of its Flight Research Dept. For design of both recording equipment and servo systems. A number of associated problems exist such as bench testing of equipment; design, fabrication, and testing of special laboratory calibrating equipment; and environmental testing for temperature, acceleration, and pressure on electrical pickups. Location Western N. Y. State. Box 627

OPTICAL ENGINEER. Required to manage production of appearance measurement instruments designed to measure Color, Gloss, and other optical properties. Should have good background and experience in optical instrument design, and ability to assist in development of new instruments. Location Maryland. Box 628

SALES MANAGER. To take complete charge of sales department of manufacturer of electrical instruments located on West Coast. Box 629

SALES ENGINEER. Large manufacturer of pressure gauges and industrial instruments has opening for mechanical or electrical engineer (or equivalent), age 25-40, to sell pressure-temperature indicators, controllers and transmitters to major industrial and engineering accounts in Western Pennsylvania and West Virginia. Must have some selling experience preferably along the lines of pressure and temperature controls. Sales-service background acceptable. Compensation $500.00 monthly plus expenses. Must own car. Box 630

INSTRUMENT INSTRUCTOR. To train instrument men in the operation and maintenance of new instruments and related equipment being added throughout plant as well as training on the operation and maintenance of conventional instruments now in the plant. To keep the instrument men informed of the many changes and modifications being added to the instruments already in use and arrange demonstrations and instructional periods where necessary. Requires a man of good mechanical ability, experienced in the maintenance of instruments and able to talk the language of the shop man. Location Michigan. Box 631

DRAFTSMEN. Piping, Electrical, Structural. Design and layout experience involving instrumentation in chemical plant or refinery desirable. Positions are permanent offering unusual opportunity for advancement. Midwest location. Box 632

INSTRUMENT MECHANICS. Openings in large oil refinery in St. Louis area. Must be experienced in pneumatic and electric controls as used in an oil refinery or chemical plant. Normal work week 40 hrs. Hourly rate $2.22. Liberal benefit plans and good working conditions. Box 633

INSTRUMENT MECHANIC. Opening in chemical and pigment plant in the St. Louis area. Must be experienced in maintenance of pneumatic controls, temperature and flow recorders. No shift work. Normal 40 hour week. Box 634

INSTRUMENT MECHANIC. Experienced in chemical or oil industry, able to repair and service all types of recording and control instruments, also electronic potentiometers. Must have a working knowledge of pneumatic control systems as applied to process control, differential type metering systems, and control valves. Location Northern Ohio. Box 635

INSTRUMENT MECHANIC. Experienced installing, repairing, testing, and calibrating major makes of instruments and controls. Proper person will be responsible for installation and maintenance of all instruments in chemical plant. Permanent position with growing company. Location Pittsburgh, Pa. Box 636

SALES ENGINEER. Mechanical engineering graduate—age 30 to 40, previous sales experience, willing to travel. Must have ability and initiative to work with Manufacturing Agents in various territories in the South and Southwest. Starting salary $5,000.00 to $6,000.00 per year, with commission arrangement at the end of the first year if successful. Box 637.

SALES ENGINEER. Sales Engineer needed to represent Instrument Company for the State of Pennsylvania. Age between 25 and 40. Engineering Degree not required, however, must have instrument background. All replies confidential. Box 638.

GOVERNMENT SERVICES

To apply for any of the following Federal Agency positions, write direct to the Agency holding the position for official application form.

U. S. Naval Ordnance Test Station, Inyokern, California

Design and development of electronic instruments for use in free flight ballistic experiments on Fin-Stabilized rockets. $5060 per annum.

Electronic research and development in the field of measurement. $5060 per annum.

Application of new theories in the field of automatic control and instrumentation. Desire extensive knowledge of servomechanisms. $5940 per annum.

Design engineer for power transmissions and distribution and detail of instrumentation facilities for ground ranges. $5060 per annum.

Theoretical design and development of specialized photographic and optical equipment and instrumentation. $5940 per annum.

U. S. Navy Electronics Laboratory, San Diego, California

Assist in planning and study phases of problems in Laboratory instrumentation and integration of man-machine combinations. Use of standard electronic test procedures and equipment should be thoroughly understood. $5060 per annum.

U. S. Naval Radiological Defense Laboratory, San Francisco, California

Research in fields of optics and spectroscopy. $8360 per annum.

Corona Laboratories, National Bureau of Standards, Corona, California

Research, design, and development work in instrumentation for ground and flight testing of guided missiles, microwave circuitry and antenna systems, or determination of complex missile systems. $3140 to $9600 per annum depending on qualifications.

Infrared radiant energy measurement and utilization; basic study of properties of infrared sensitive detectors and related instrumentation. Duties of position can be varied to fit qualifications of applicants. Electronic specialization primary requirement with knowledge of optics, quantum mechanics, radiometry, spectroscopy, or solid state physics desirable. PhD in physics desirable for higher salary levels. $5060-$7040 per annum.

Cleveland Show Largest Ever

The Seventh National Instrument Conference and Exhibit already promises to be the largest ever held. At the time of mailing the general sale (January 28th), 178 booths, representing 19240 sq. ft. of exhibit space, had been sold. In addition to the 79 companies reported in the January *ISA Journal*, the 25 companies listed below have reserved exhibit space:

Anderson & Sons
Automatic Electric Sales
Automatic Temperature Control Co.
Brush Development Co.
Buffalo Meter Co.
Cameron Iron Works
Carboloy Dept., G. E.
Cook Electric Co.
R. W. Cramer Co.
General Mills, Inc.
Hankison Corp.
Helicoid Gage Div.
Hickok Electrical Inst. Co.
Hills McCanna Co.
Jerguson Gage & Valve Co.
Lord Mfg. Co.
McAlear Mfg. Co.
Metrotype Corp.
National Spectrographic Labs.
Penberthy Injector Co.
Permutit Co.
Research Controls
Surprenant Mfg. Co.
Uehling Instrument Co.
Victoreen Instrument Co.

The general sale of available space was originally scheduled for January 10th, but it was not possible to obtain delivery of the necessary material from the printer by that date. The mailing for the general sale, therefore, went forward on January 28th.

It is expected that hotel reservation information will be published in the March *Journal*.

ASME Cleveland Program

The Industrial Instruments and Regulators Division of the American Society of Mechanical Engineers will have a Symposium on High Pressure Measurements and Techniques at the Seventh National Instrument Conference.

Paul Exline, Chairman of the Design Committee of the Industrial Instruments and Regulators Division and past president of the ISA, advises that Bill Howe, who is in charge of the arrangements for this session, has lined up a group of papers of unusually high caliber. Also, Dr. Bridgman, who received the Nobel prize for work in this field, will be the kick-off speaker.

Exline reports indications that a large number of men, especially interested in this field, will be in Cleveland in September.

Plan NOW
to attend the
7th National Instrument Conference & Exhibit
September 8-12, 1952
Cleveland Public Auditorium

Section Secretaries, Meeting Data and Programs

AKRON
Russell F. Marquardt, 1782 Tonawanda Ave., Akron 5, Ohio. Tel: ST-6865
Fourth Tuesday, Meeting 8:15 P.M., U. of Akron, Ayer Hall, Rm. 212-B.

ALBUQUERQUE
W. E. Bostwick, 304 So. Princeton, Albuquerque, N. Mex.
First Monday, Meeting at 8:00 P.M., Mitchell Hall, Univ. of N. M.

ARUBA
J. L. Lopez P. O. Box 203, c/o Lago Oil & Transport Co. Ltd., Aruba, N. W. I. Tel. 2087.
First Tuesday, 7:30 P. M., Engr's Club.

ATLANTA
M. Virgil Davis, 357 Sixth St., N.W. Atlanta, Ga. Tel. EM. 3042
Fourth Friday, Meeting 7:30 P.M., Electric Bldg., Georgia Power Co.

BALTIMORE
G. B. Greer, 631 East 36th St., Baltimore 18, Md. Tel: CHesapeake 6879
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
John Q. Bass, 1571 Longwood Dr., Baton Rouge, La. Tel: 3-0283
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 7:30 P. M., 99 Club, 99 State St.

CALIFORNIA
Gerald B. Miller, 4622 Halbrent Ave., Sherman Oaks, Calif.
Second Wednesday. Dinner at 6:30 P. M. Meeting at 8:00 P. M., Carolina Pines, 7315 Melrose Ave., Los Angeles

CENTRAL ILLINOIS
H. R. Getz, 723 Laura Ave., Peoria 5, Ill. Tel: 4-2800
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
Norman Krone, 123 N. Grant Ave., Indianapolis, Ind. Tel. IRvington 5337
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
H. G. Murray, 169 Durston Ave., Syracuse 6, N. Y. Tel: 9-9259
Third Monday, Dinner at 6:00 P. M., Meeting at 8:00 P. M.

CHARLESTON
D. A. Cunningham, 5140 Washington Ave., S.E., Charleston, W. Va. Tel. 55403
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Airport Terminal Bldg.

CHICAGO
Floyd E. Ertsman, Rm. 1420, Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P.M., Hotel Shoreland.
Mar. 3, Subject: Analysis Instrumentation. Sponsored by Committee on Analysis.
Apr. 7, Subject: Instrumentation in Auto and Tractor Industry. To be held at Museum of Science and Industry. Sponsored by Committee on Transportation Instrumentation.

CHINA LAKE
A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

CINCINNATI
R. J. Eichner, 1900 Courtland Ave., Norwood 12, Ohio. Tel: Jefferson 3130
Second Monday, Dinner at 6:30 P.M., Meeting 8:00 P.M., Engineering Soc. of Cinn.

CLEVELAND
G. D. Carnegie, 3436 Lorain Ave., Cleveland, Ohio.
Second Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, 2136 E. 19th St.

COLUMBUS
E. M. Chandler, 91 E. Como Ave., Columbus 2, Ohio. Tel: JE 9994.
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecelia St., Cumberland, Md. Tel: 583-W
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Alighan Shrine Country Club, Baltimore Pike.

DENVER
G. M. Peters, 3191 W. Denver Place, Denver 11, Colo. Tel: GRand 9073

DETROIT
Frank R. Davis, Edison Institute, Dearborn, Mich. Tel: LO 1-1620 Ext. 5517
Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.

EASTERN NEW YORK
Robert W. Carter, Sterling-Winthrop Research Institute, Rensselaer, N. Y. Tel. Albany 5-6251 Ext. 262
First Tuesday, Meeting at 8:00 P.M., Siena College, Loudonville, N. Y. Optional Dinner at 6:00 P.M., Circle Inn, Lathams, N. Y.

GULF COAST
Harold Placette, 2440 Neches Ave., Port Arthur, Texas
Third Tuesday. Meeting at 7:30 P.M., Lamar College, Beaumont, Texas.

HOUSTON
I. K. Farley, Brown Instrument Co., 2123 Travis St., Houston, Texas, Tel: Charter 2511.
Last Monday, Meeting at 8:00 P.M., University of Houston Library Building.

KANSAS CITY
J. C. Brous, 8827 Maiden Lane, Kansas City 5, Mo.
First Tuesday, Meeting at 7:30 P.M., U. of Kansas City, Science Bldg., Rm. 106.
Mar. 4, Subject: Pneumatic versus Electronic Controls for Pipeline and Booster Stations. Speaker: S. S. Smith, Shell Pipe Line Co.
Apr. 8, Subject: Electro-Mechanical Measurement, Amplification, and Transmission. Speaker: Garland Roper, Manning, Maxwell and Moore.

LOUISVILLE
C. M. Bosworth, 203 Arbor Park, N., Lo., Ky.
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
L. E. Henne, Bristol Co. of Canada Ltd., 712 Dominion Square Bldg., Montreal, Quebec, Canada Tel: UNiversity 6-4725.
Last Monday, 8:00 P.M., Mechanic's Institute.

NEW JERSEY
L. H. Ballinger, 2371 Channing Ave., Westfield, N. J. Tel: Westfield 2-0765M
First Tuesday. Meeting at 8:00 P.M., Essex House, Newark.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.

NIAGARA FRONTIER
Mrs. James L. Martin, 34 Manning Rd., Eggertsville 21, N. Y. Tel: WIndsor 0087
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
Bert L. Anderson, 1951 47th Ave., San Francisco 16, Calif. Tel: SEabright 1-5030
Third Monday. Dinner 6:30 P. M., Meeting 8:00 P.M., Spengers Grotto, 1919-4th St., Berkeley.

NORTHERN INDIANA
J. Baum Beckman, 7145 Wicker Ave., Hammond, Ind. Second Tuesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.
Mar. 11, Subject: Television in Industry. Speaker: G. H. Wilson, Diamond Power Specialties Co.
Apr. 8, Subject: The Application of Plug and V-Port Valves. Speaker: From Fisher Governor Co.

OAK RIDGE
George Ritscher, 113 Gorgas Lane, Oak Ridge, Tenn. Tel. 5-1084
First Wednesday, Meeting at 7:30 P.M., Ridge Recreation Hall

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
Bruno F. Loewen, Philips Chem. Co., Box 1526, Borger, Texas.
Third Tuesday. Meeting at 8:00 P.M.

PERMIAN BASIN
J. B. Jenkins, 509 South Ave. "C," Kermit, Texas.

PHILADELPHIA
R. A. Trenner, Energy Control Co. Rm. 306, 3147 N. Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellevue-Stratford Hotel.
Feb. 20, Subject: Panel on Instrumentized Weighing.

PITTSBURGH
W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa., Tel. Express 1-1330
Fourth Monday, Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.
Feb. 25, Section Program, Subject: Modern Process Control for Blast Furnace Control. Speaker: Otto J. Leone, Consulting Engineer.
Program of the Technical Committee on Inspection and Gaging, Subject: Inspection of Pipe and Plate Products. Speaker: L. W. Seeger, National Tube Co.
Program of the Technical Committee on Industrial Instrument Maintenance, Subject: Demonstrations on the Repair, Set-up, and Adjustment of Instruments made by the Brown Instrument Div., Minneapolis-Honeywell Regulator Co., by a Service Representative of that Company.
April 3-4, Conference Sponsored by Pittsburgh Section ISA and Carnegie Institute of Technology, Subject: Instrumentation for the Iron and Steel Industry.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.
Feb. 26, Subject: Measurement and Control of Temperature. Speaker: from Brown Instrument Co.
Mar. 25, Subject: Control Valves and Positioners. Speaker: From Fisher Governor Co.

RICHLAND
T. H. Quinn, 1513 Goethals Dr., Richland, Wash. Tel: 7-8717
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
L. J. Hall, 730 Talfourd St., Sarnia, Ont., Canada. Tel: EDgewater 2258.
Second Monday, 8:00 P.M., Moose Hall.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

SOUTHERN MICHIGAN
Lyle J. Draper, 2233 Oakland Dr., Kalamazoo, Mich.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516.
First Wednesday After First Monday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.
Mar. 5, Subject: Pneumatic versus Electronic Controls for Pipeline and Booster Stations. Speaker: S. S. Smith, Shell Pipe Line Co.
April 9, Subject: Electro-Mechanical Measurement, Amplification, and Transmission. Speaker: Garland Roper, Manning, Maxwell and Moore.

TOLEDO
P. H. Girkins, 418 Waggoner Blvd., Toledo 12, Ohio. Tel: LA 6505
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
James L. Williams, 2237 Bruce St. Kingsport, Tenn. Tel: 2079-L
Fourth Thursday, Civic Auditorium.

TULSA
S. M. Bagwell, 1544 E. 35th Pl., Tulsa 5, Okla. Tel: 7-6822
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.
Mar. 3, Subject: Pneumatic versus Electronic Controls for Pipeline and Booster Stations. Speaker: S. S. Smith, Shell Pipe Line Co.
Apr. 7, Subject: Electro-Mechanical Measurement, Amplification and Transmission. Speaker: Garland Roper, Manning, Maxwell and Moore.

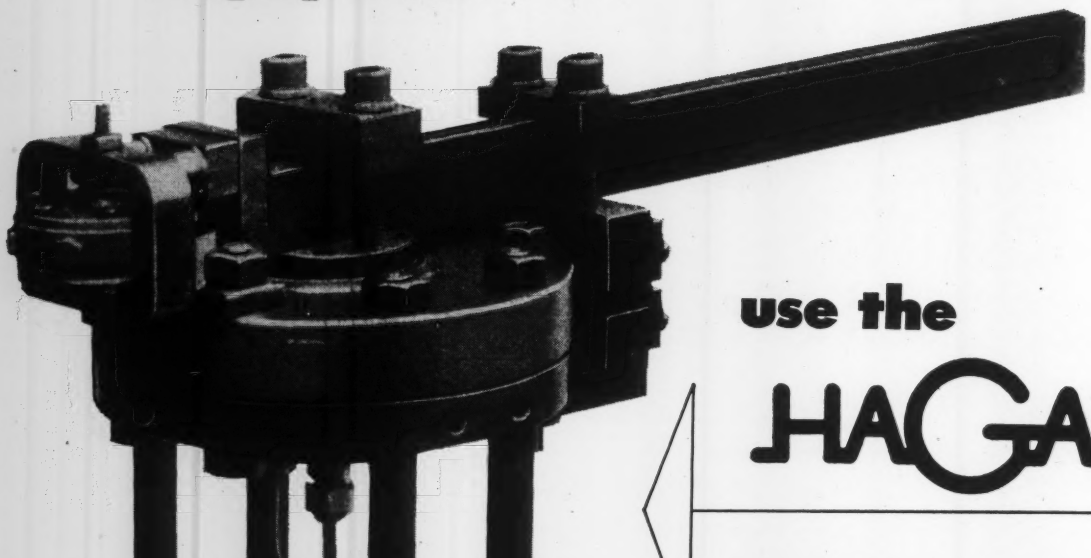
TWIN CITIES
Jerome J. Schwab, Engineering Sales, 516 Guardian Bldg., St. Paul 1, Minn. Tel: GArfield 0601
Fourth Tuesday, Dinner at 6:30 P.M., Meeting 7:30 P.M., Rm. 353, Coffman Memorial Union, U. of Minn.

WASHINGTON
Raymond E. Miller, 1-205 Naval Ord. Lab., White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
J. R. McCauley, 18073 Archdale, Detroit 19, Mich. Tel: KE 1-5239.
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
J. E. Charsha, Jr., Hammel-Dahl Co., 1000 Washington St., Wilmington 11, Del. Tel: 2-6694
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

for versatile force measurement equipment . . .



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- **rocket thrust measurement**
- **testing piston rings**
- **torque measurement of helicopter engines**
- **jet engine thrust measurement**
- **chassis dynamometers**
- **axle testing machines**
- **portable test stands for planes**
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JOURNAL of the
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Vice-President: F. M. Partridge
Secretary-Treasurer: Geo. H. Forster, Jr., 2916 Eucalyptus Ave., Long Beach 6, Calif.
Auditor: C. B. McKinney
Past President: James E. Adams

Fundamentals of Orifice Measurement

By F. M. PARTRIDGE, Southern California Gas Co.

History

THE first record of the use of orifices for the measurement of fluids was by Giovanni B. Venturi, an Italian physicist. In 1797 he did some work with various orifices, and later developed the Venturi meter, which bears his name. It has been reported that an orifice meter designed by Professor Robinson of Ohio State University was used to measure gas near Columbus, Ohio at about 1890.

About 1903 Mr. T. R. Weymouth began a series of tests in Pennsylvania, which led to the publication of coefficients for orifice meters with flange taps. At the same time Mr. E. O. Hickstein made a similar series of tests at Joplin, Missouri, from which he developed data for orifice meters with pipe taps.

At this time, differentials were measured and instantaneous readings were observed by means of a glass-tube water manometer. A satisfactory recording-type meter was developed by use of a mercury manometer (Fig. 1).

A large amount of research and experimental work was conducted by the American Gas Association and the American Society of Mechanical Engineers between 1924 and 1935 in developing orifice-meter coefficients and standards of construction for orifice meters. In 1935 a joint A.G.A.-A.S.M.E. report was issued titled "History of Orifice Meters and the Calibration, Construction, and Operation of Orifices for Metering." This report is the basis for almost all present-day orifice-meter measurement. Several additional bulletins have been prepared to simplify the measurement of gas by orifice meter. These are: "Gas Measurement Committee Report No. 2," Natural Gas Department, American Gas Association (1935), and California Natural Gasoline Association Bulletins TS-353 (1935) and TS-402 (1941).

Presented at SCMA's "Instrument Maintenance Short Course" at Los Angeles Harbor Junior College, Nov. 15-17, 1951.

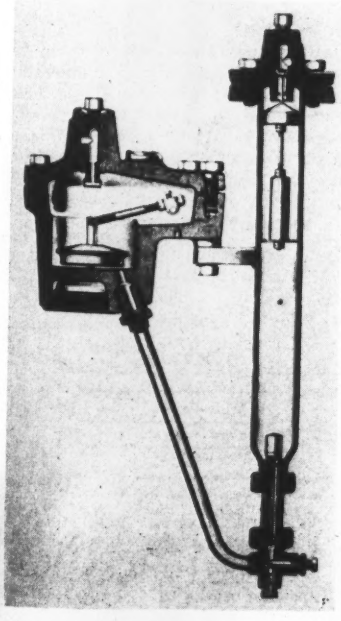


Fig. 1. Recording-type mercury monometer.

What Is It?

An orifice meter is a conduit with a restriction to create a pressure drop. An hour glass is a form of orifice meter. A nozzle, Venturi meter, or even an elbow can be used as the flow restriction. Fig. 2 shows one type of elbow meter.

In order to use any of these devices for measurement, it is necessary to calibrate it. Calibration is done by passing a known volume through the meter and noting the reading, which provides a standard for measuring other quantities.

Owing to the ease of duplicating and its simple construction, the thin sharp-edged orifice has been adopted as a standard; extensive calibration work has been done so that it is accepted widely as a standard means of measuring fluids. An orifice in a pipeline is shown in Fig. 3, with a manometer for measuring the pressure drop (differential) as the fluid passes through the orifice. The minimum cross sectional area of the jet (point II) is known as the "vena contracta." The volume passing is approximately equal to the area of the "vena contracta" multiplied by the velocity and density of the fluid.

How Does It Work?

Fig. 4 shows the change in pressure of the fluid as it approaches and leaves the orifice plate. The taps shown are *throat taps*, which are located 1 pipe diameter upstream and ½ pipe diameter downstream. For small pipe sizes this downstream tap is fairly close to the "vena contracta." Other types of

March Meeting: Thursday, the 20th, 1952, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30, meeting at 8:00 P.M.

Feature: "Electrical Transmitting and Transducing of Process Measurements" by C. G. Roper, Manning, Maxwell & Moore, Inc.

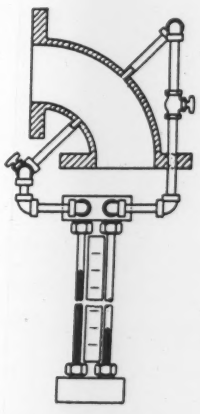


Fig. 2 (Left). Diagram of elbow meter.

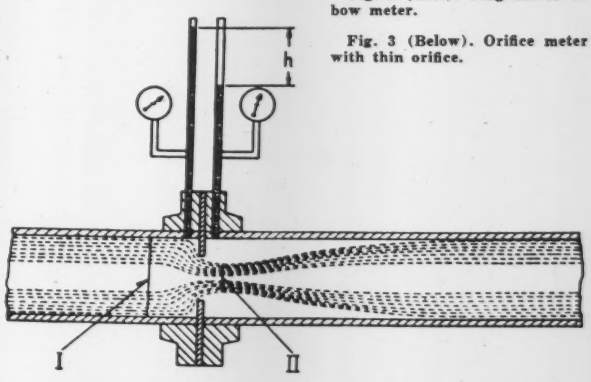


Fig. 3 (Below). Orifice meter with thin orifice.

pressure taps are corner taps, pipe taps, and flange taps. *Corner taps* are located immediately adjacent to plate face; *pipe taps* are 2½ diameters upstream and 8 diameters downstream; *flange taps* are 1 inch upstream and downstream from the plate.

Corner taps are used commonly in Europe. Pipe taps and flange taps are used in this country, with flange taps preferred on the Pacific Coast (C.N.G.A. Bulletin TS-353, page 21).

As the fluid approaches the orifice the pressure increases slightly and then drops suddenly as the orifice is passed. It continues to drop until the "vena contracta" is reached. It then gradually increases until, at approximately 8 pipe diameters downstream, another maximum pressure point is reached. The decrease in pressure as the fluid passes through the orifice is a result of the increased velocity of the gas passing through the reduced area of the orifice. This is in accordance with Bernoulli's Theorem:

$$V_1^2/2g+P_1 = V_2^2/2g+P_2+H_L$$

in which $V^2/2g$ is the velocity head at a given point, P is the pressure at the same point, and H_L is the pressure drop due to friction and turbulence.

When the velocity decreases as the fluid leaves the orifice, the pressure increases and tends to return to its original level. All the pressure loss is not recovered because of friction and turbulence losses in the stream.

The pressure drop across the orifice increases when the rate of flow increases. When there is no flow there is no differential. The differential pressure is proportional to the square of the velocity. Therefore, it follows that if all other factors remain constant, the differential is proportional to the square of the rate of flow.

With an orifice meter constructed in accordance with A.G.A. or A.S.M.E. standards, acceptable accuracy in measurement can be obtained using a suitable recording differential-pressure gage (such as shown in Fig. 1) and a properly computed coefficient.

Fundamental Gas Laws

All substances are composed of molecules, which are the smallest units into which a substance can be divided without losing its identity. For example, natural gas is composed of molecules of methane, ethane, etc. These molecules are in constant motion. It is the impact of these molecules on the sides of a container which causes pressure. As the speed of the molecules depends on temperature, an increase in temperature increases the motion of the molecules, which in turn increases the pressure.

As decreased temperature and pressure causes decreased motion of the molecules, it follows there must be some point where there is no molecular activity. The points where there is no molecular activity are absolute zero temperature (approximately minus 460 degrees F.) and absolute zero pressure (approximately 14.7 pounds per square inch below atmospheric pressure). Absolute pressure is equal to gage pressure plus barometric pressure (14.7 psi.). Absolute temperature is equal to degrees Fahrenheit plus 460 degrees.

The volume of a gas depends on its absolute temperature and pressure. *Boyle's law*, which expresses the relation between volume and pressure, states that the volume of a gas is inversely proportional to its absolute pressure, providing temperature is constant.

Charle's law relates the volume and temperature of a gas. This law states that the volume of a gas is directly proportional to its absolute temperature, providing the pressure is constant.

The combined Boyle's and Charle's law is commonly written in the form of the equation:

$$P_1V_1/T_1 = P_2V_2/T_2$$

which is very useful in solving gas problems at ordinary temperatures and pressures.

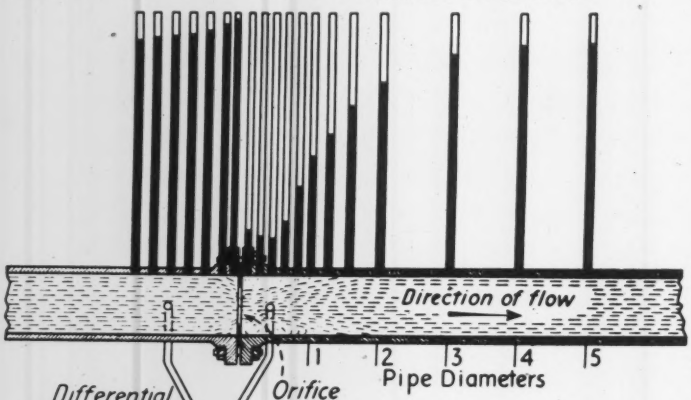


Fig. 4. Principle of flow measurement.

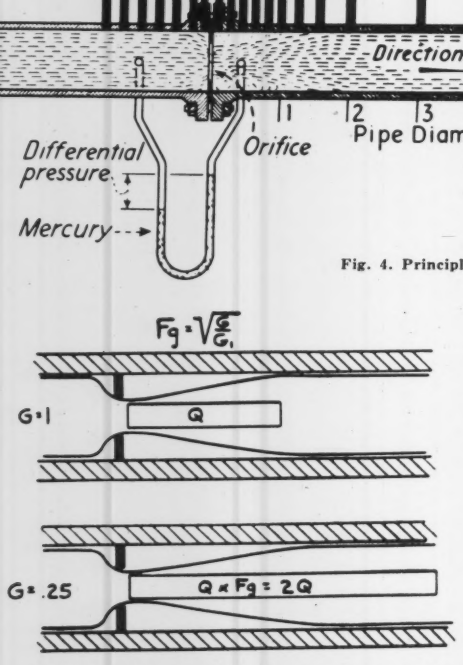
Factors Used in Gas Measurements

Specific Gravity

When a given force is applied on two gases of different specific gravity, a larger volume of the lighter gas is pushed through the orifice. As the flow varies according to the square-root law, twice as much gas having a specific gravity of 0.25 flows through the orifice as does gas having a specific gravity of 1.0 (Fig. 5).

Temperature

Temperature has two effects on flow volume. First, as a higher temperature means a lighter gas, more gas flows; but when this higher flow is corrected to base temperature, the volume is decreased by the first power. Fig. 6 shows the result. In the second section, a temperature of 1040 degrees (absolute) causes the weight to be reduced



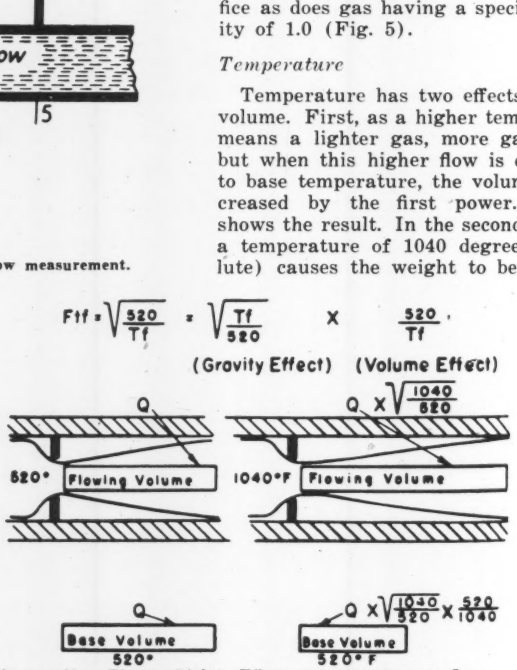


Fig. 5 (Left). Effect of specific gravity (G) on flow through an orifice. Fig. 6 (Right). Effect of temperature on flow.

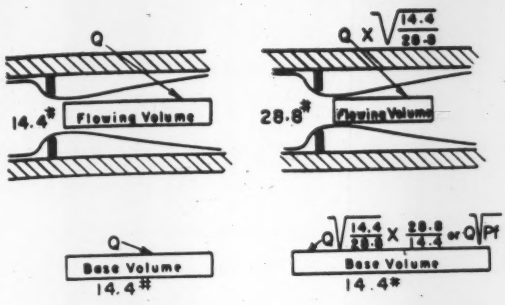


Fig. 7 (Above). Effect of line pressure on flow.

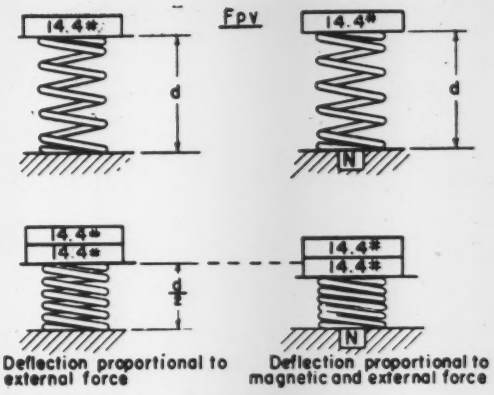


Fig. 8 (Right). Analogy to illustrate supercompressibility.

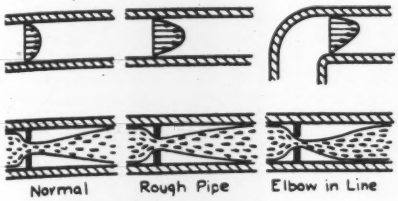


Fig. 9. Effect of velocity distribution, or eccentric location of orifice plate, on flow pattern.

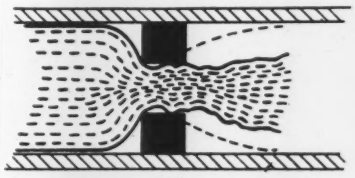


Fig. 10. Effect of orifice-plate thickness.

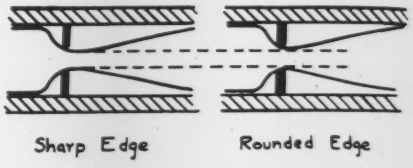


Fig. 11. Effect of orifice edge.

by one-half. Thus the volume is increased by $\sqrt{2}$. When this is changed to the temperature base of 520 degrees, the volume is cut in half. The result is 70.7 percent of original flow.

Pressure

Fig. 7 shows that pressure, like temperature, has a double effect on flow volume. As the higher pressure makes the gas heavier, less volume flows through the orifice; but when this volume is expanded to the base pressure, the volume is increased. The result is 141 percent of original flow when the pressure is doubled.

Supercompressibility

Boyle's law states that when pressure is applied to a gas, the volume decreases proportionally. In practice, the volume decreases more than this amount because as the gas molecules get closer together the attraction between molecules brings them closer together. An analogy to the supercompressibility effect is shown in Fig. 8. If a spring of length "d" has a force of 14.4 pounds acting on it, it can be so designed that a force of 28.8 pounds decreases this length to "d/2." If the top and bottom plates are now changed to magnets which have an attraction for each other, the 28.8-pound force causes the length to be less than "d/2" because of the extra force obtained from the magnets.

Expansion Factor

In computing the flow rate the pressure at the orifice edge is desired. However, as it is difficult to measure at that point, a correction known as the expansion factor is made.

Reynold's Number

The Reynold's number is a dimensionless number which relates the effect of viscosity, pipe diameter, velocity, and density.

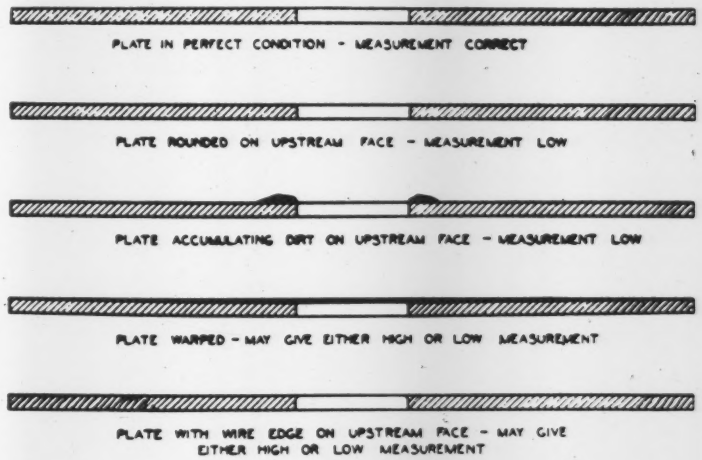


PLATE IN PERFECT CONDITION - MEASUREMENT CORRECT
PLATE ROUNDED ON UPSTREAM FACE - MEASUREMENT LOW
PLATE ACCUMULATING DIRT ON UPSTREAM FACE - MEASUREMENT LOW
PLATE WARPED - MAY GIVE EITHER HIGH OR LOW MEASUREMENT
PLATE WITH WIRE EDGE ON UPSTREAM FACE - MAY GIVE EITHER HIGH OR LOW MEASUREMENT

Fig. 12. Effect of orifice-plate condition on measurement.

Possible Causes of Measurement Errors

Fig. 9 shows the effect of velocity distribution on measurement. At the left are shown side and top views of the normal flow condition. The other two sections show how an erratic reading can result from rough pipe or an orifice too close to an ell. An eccentric orifice causes a condition similar to that shown for the ell.

There is no minimum thickness for an orifice plate. However, if it is too thick the condition shown in Fig. 10 can exist. This condition causes turbulence and friction in the orifice. The friction decreases the rate of flow through the plate.

The condition of the upstream edge is extremely important. A slightly rounded edge (Fig. 11) increases the area of the vena contracta and allows more gas to pass for a given differential. On a 1-inch orifice, a 1/32-inch radius roundness of the upstream edge increases the flow rate approximately 10 per cent. A radius of 0.0005 is noticeable and causes an error of 2 per cent. The smaller the plate the more important it is to maintain a square upstream edge.

Several common departures from good plate-maintenance procedures are illustrated in Fig. 12. The probable effect on accurate measurement is indicated.

Acknowledgements

Much of the material for this article has been obtained from publications of the American Meter Company, the Foxboro Company, and the Rockwell Manufacturing Company. Figs. 5 to 11 are taken from a paper by Mr. Howard J. Evans, Pittsburgh Equitable Meter Division of Rockwell Manufacturing Company, which was presented at the Southwestern Gas Measurement Short Course, University of Oklahoma, April 1948.

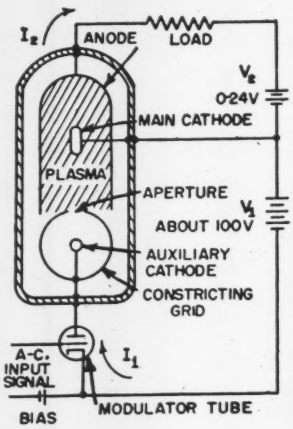
INSTRUMENTS ON THE MARCH

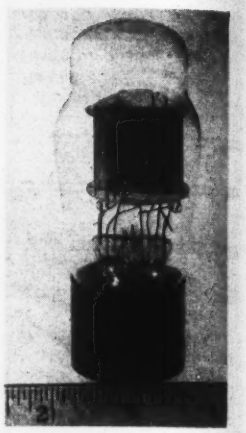
New Principles, Applications, Non-commercial Developments

Controllable Gas Diode

PRINCETON, N. J.—A new development in gas tubes, the *plasmatron,* may overcome the basic disadvantage of gas tubes—lack of continuous grid control. A *plasma* is a region in which positive ions and negative electrons both exist. As recombination between the ions and electrons occurs continuously, the plasma has the familiar blue glow seen in all gas tubes. The glow occurs when recombination takes place.

In the plasmatron, an auxiliary cathode forms a current (I_1) that controls the density (and hence the conductivity) of the plasma. As the conductivity of the plasma determines the main plate current (I_2) of the tube, the main current is controlled by the auxiliary current. The auxiliary current is continuously controllable by an auxiliary tube and provides a means by which the plate current of the gas tube can be controlled continuously. The auxiliary tube can be a conventional triode, such as a 6J5. A controllable gas diode would have tremendous application in industrial electronic circuits. The tube is in the developmental stage at the RCA Laboratories Division, Radio Corp. of America, Princeton, N. J.

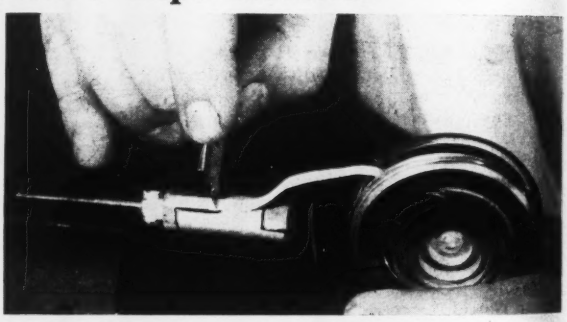




High-temperature Adhesive Tape Resistor

WASHINGTON, D.C.—Printed electric circuits—in which components and wiring are superimposed directly on insulating bases—are being used increasingly because they facilitate miniaturization of equipment. A new adhesive-tape-resistor method recently devised by the National Bureau of Standards, makes it easy to incorporate the resistors in circuits, according to Technical Report 1540.

In this technique, circuits first are printed in narrow metallic bands on insulating bases, leaving a small gap at each point where a resistance is required; a self-adhesive resistor then is cut from a strip and pressed into position. The NBS tape resistor operates satisfactorily at temperatures to 200 C; in other electrical characteristics it is similar to film-type carbon resistors.



Analysis of Solids in the Mass Spectrometer

WASHINGTON, D. C.—A simple practical technique now makes possible the application of the mass spectrometer to the quantitative analysis of solids, according to Technical Report 1545. Developed at the National Bureau of Standards, the new procedure yields highly accurate, easily interpreted results with much greater speed and convenience than chemical methods.

In the mass spectrometer (Fig. 1), materials to be analyzed are first converted into positive ions. The ions then are passed through crossed electrostatic and magnetic fields, where they are deflected by varying amounts depending on their mass and charge. The intensities of the separated ion beams are detected either photographically or electrically and are used to determine the quantity of each material present.

A monitoring collector (Fig. 2) placed in the path of the unseparated ion beam provides a measure of the total ions of all masses that are given off by the spark source at any instant. After separation, the currents due to ions of different masses are measured, and a pen-and-ink recorder records the ratios of each of these ion curents to the total ion current measured by the monitoring electrode. As the total and the partial ion currents tend to fluctuate in the same manner, the ratio obtained on the recorder is constant

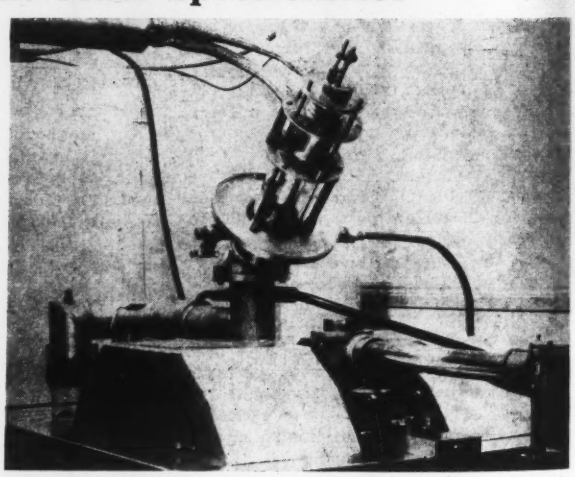


Fig. 1. Mass spectrometer for analysis of solids. The ions produced in the cylindrical enclosure pass through the field of a large magnet in the bottom of the unit.

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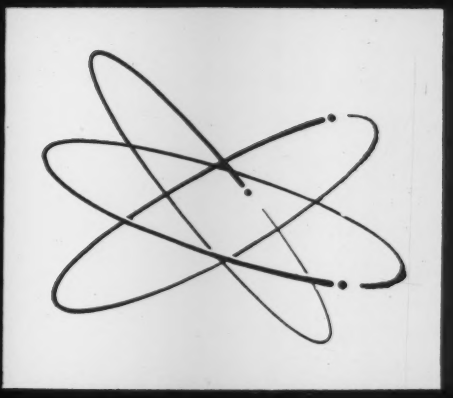

of pressure

temperature

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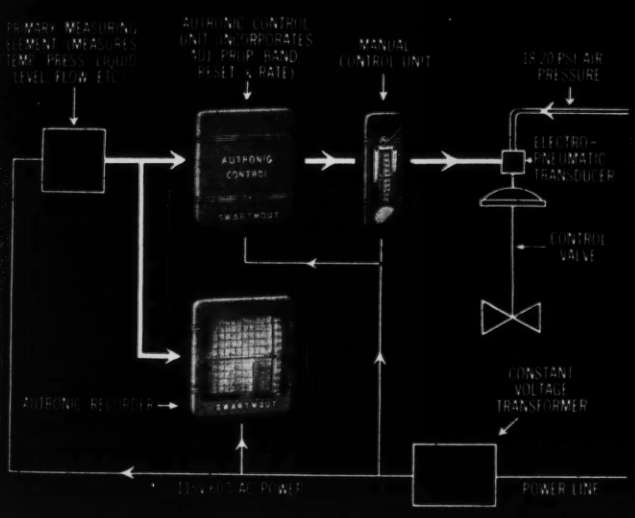

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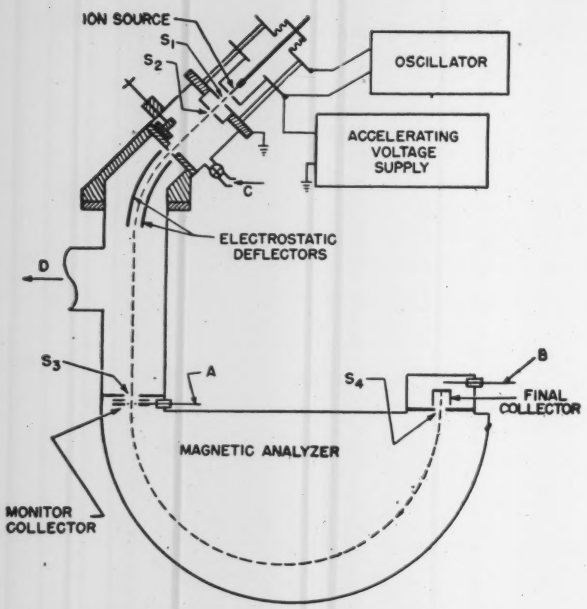


Fig. 2. Schematic diagram of mass spectrometer for solids. For any one value of magnetic field, only one type of ion enters final collector.

for ions of a given type so long as their concentration in the sample does not change.

Ions are obtained by using a rod of the sample material as one electrode in a vacuum spark discharge and are separated according to mass in a modified mass spectrograph of the Dempster type. The ions from the source are first accelerated through a pair of limiting slits by the application of a large potential difference. They then enter an electrostatic field, where each ion is deflected through an angle of a magnitude depending on its individual velocity; this permits only those ions in a narrow energy band to pass through the slit at the entrance to the magnetic analyzer. Within the analyzer, a uniform magnetic field perpendicular to the electrostatic field causes the ions to move in a circular path toward the terminal slit and the final collector. The radius r of the circle in which an ion of a certain kind must travel is determined by its velocity v, its mass M, and its charge E, as well as the intensity of the magnetic field H, according to the equation:

$$HEv = Mv^2/r.$$

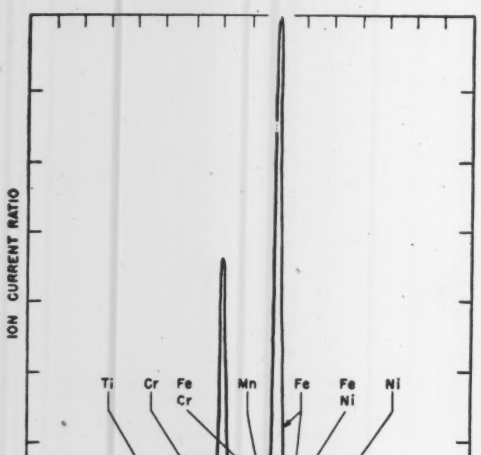


Fig. 3. Mass spectrum of sample of stainless steel.

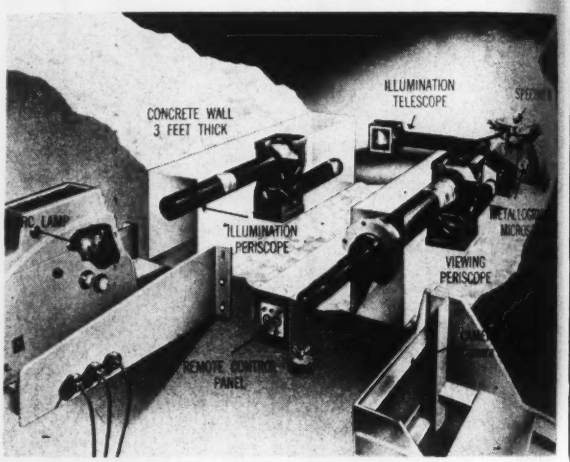
For given values of E/M and accelerating potential, the value of r, and therefore of the current registered by an electrometer connected to the final collector, depends on the applied field, H.

In the NBS method, the magnetic field is varied so as to sweep ions of different masses across the exit slit of the magnetic analyzer. The measured ion currents are amplified, and the automatic recorder records the ratios of the currents at the final ion collector to the current at the monitoring collector. From the measured value of the magnetic field and the other constants of the apparatus, the mass number corresponding to each ion beam is found. Then, when the ion current ratios are plotted against mass number, sharp peaks are obtained corresponding to the ions of different masses present in the sample. Fig. 3 shows a mass spectrum of a sample of stainless steel.

It is expected that the technique will prove feasible also for the analysis of nonmetallic solids.

Microscopic Study of Radioactive Materials

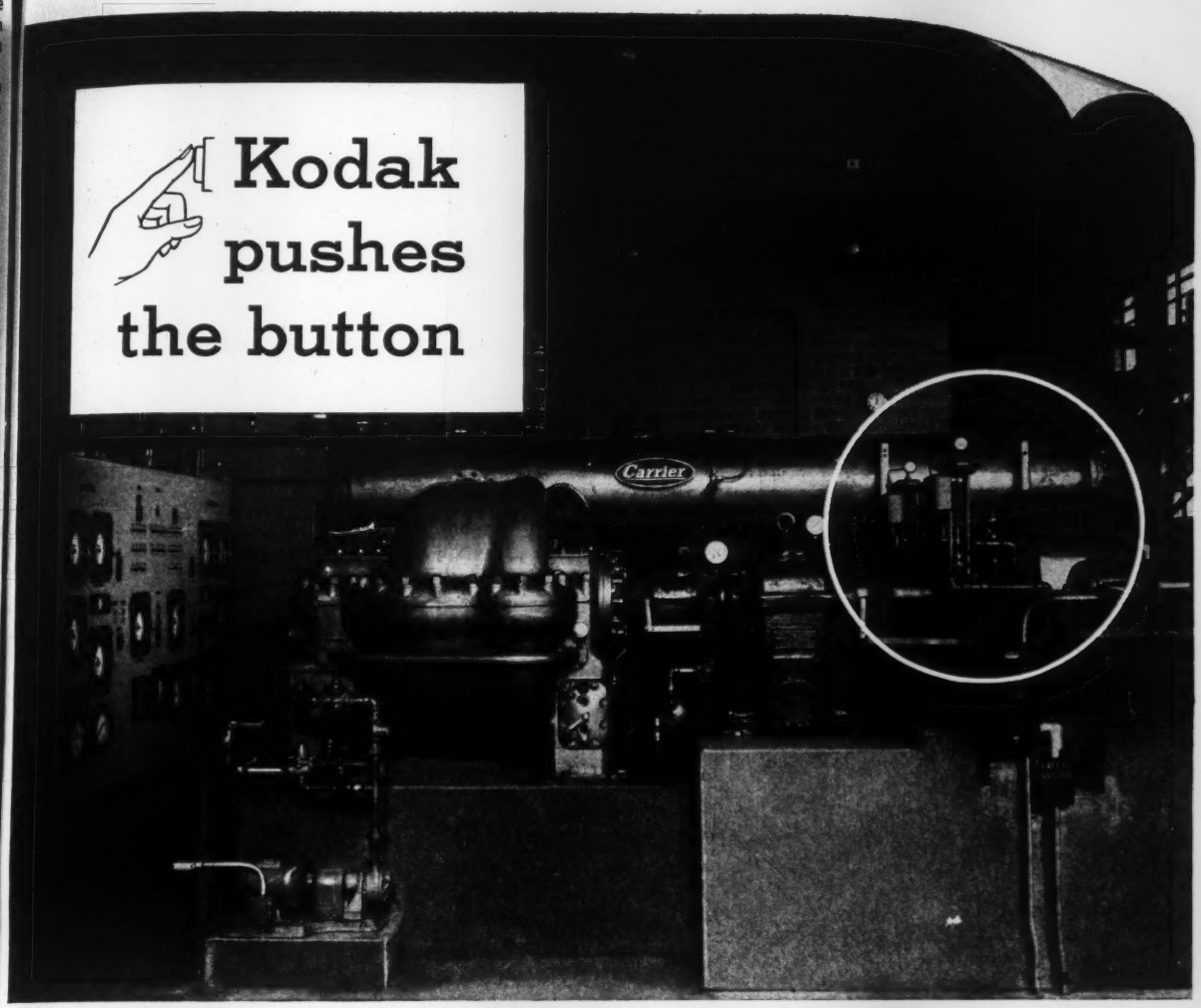
SCHENECTADY, N. Y.—The illustration shows the operation of a remotely-controlled microscope made by the American Optical Company's Instrument Division for the Knolls Atomic Power Laboratory, which is operated at



Schenectady, N. Y. by the General Electric Company for the Atomic Energy Commission. With its aid, scientists may safely examine highly radioactive metal specimens located inside a test chamber with three-foot concrete walls. Two periscopes are provided—one to carry in light to the specimen, the other to bring out its magnified image, so it may be examined visually or photographed. The offsets in the periscopes trap harmful radiations.

Graduate Courses in Instrumentation

CLEVELAND, Ohio—The Case Institute of Technology announces 3 graduate courses in Instrumentation for the spring term, Feb. 4 to May 31, 1952. The courses are in the Mechanical Engineering Department. Course ME 161, "Instrumentation and Automatic Control," is on fundamentals of industrial process control, and will be taught by visiting Professor N. H. Ceaglske from the University of Minnesota. Course ME 167, "Design of Instrumentation Equipment," is on design-analysis techniques for process control, machine servomechanisms, and governors, and will be taught by Professor Eckman and Professor Wright. Course ME 265, "Principles of Process Control," is an advanced theoretical course in automatic control, spectral density, and phase-plane methods. It will be taught by Professor Eckman.



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Calendar of Important Instrumentation Events

1952

Mar. 3-6
Institute of Radio Engineers.
National Convention and Exhibit.
Waldorf-Astoria Hotel and Grand Central Palace, New York City.

Mar. 5-7
Analytical Chemistry Group, Pittsburgh Section, American Chemical Society and Pittsburgh Spectroscopy Society Conference on Analytical Chemistry and Applied Spectroscopy. For information write to J. R. Churchill, P.O. Box 772, New Kensington, Penna.

April 1
New Jersey Section, ISA, Symposium "Use and Application of Control Valves." For information write L. H. Ballinger, 2371 Channing Ave., Westfield, N. J.

April 3-4
Instrument Society of America, Pittsburgh Section.
Second Annual Regional Conference, "Instrumentation for the Iron and Steel Industry."
Roosevelt Hotel, Pittsburgh.
For information write W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa.

April 3-8
36th Annual Exhibition of Scientific Instruments and Apparatus, Royal College of Science, London, England. For information write Physical Society, 1 Lowther Gardens, London, S.W. 7, England.

April 27-May 6
Heavy Industries Fair, Hanover, Germany. This fair includes exhibits of instruments for measurement, inspection, testing and control. For information write Deutsche Messe- und Ausstellungs-A.G., Hannover, Messegelaende, Germany.

May 1952
American Association of Spectrographers. Symposium on "Instrumental Methods of Analysis in the Non-Ferrous Industry." Contributed papers in this field are invited, write to Robert Raisig, c/o Apex Smelting Co., 2537 W. Taylor St., Chicago 12, Ill.

May 2-3
Association for Computing Machinery, Spring meeting. For information write F. A. Schwertz, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh 13, Penna.

May 4-8
Electrochemical Society, Fiftieth Anniversary Meeting, Benjamin Franklin Hotel, Philadelphia. Sessions on Instrumentation have been scheduled. For information write Dr. Henry Linford, Sec., 235 West 102 St., New York 25.

May 5-16
British Industries Fair. Earls Court & Olympia, London includes laboratory and scientific instruments; Castle Bromwich, Birmingham, includes industrial instruments. For information write Board of Trade, Imperial Chemical House, London, S.W.1, England.

May 6-9
Scientific Apparatus Makers Association.
Annual Meeting of all Sections.
Edgewater Beach Hotel, Chicago.

May 7-9
Institute of Radio Engineers.
National Conference on Airborne Electronics.
Biltmore Hotel, Dayton, Ohio.
For information write E. K. Gannett, 1 East 79th St., New York 21.

May 14-16
Society for Experimental Stress Analysis, Spring meeting, Lincoln Hotel, Indianapolis, Ind. For information write V. H. McNeilly, 1207 Parkway Court, Lafayette, Ind.

May 16-17
Southwestern Institute of Radio Engineers.
Conference and Radio Engineering Exhibit.
Rice Hotel, Houston, Texas.

May 18-25
Achema X—Chemical Meeting and Exhibit, Frankfurt, Germany. At the same time and place the 25th International Congress for Industrial

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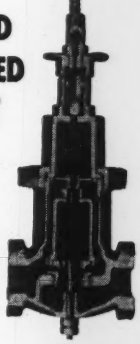

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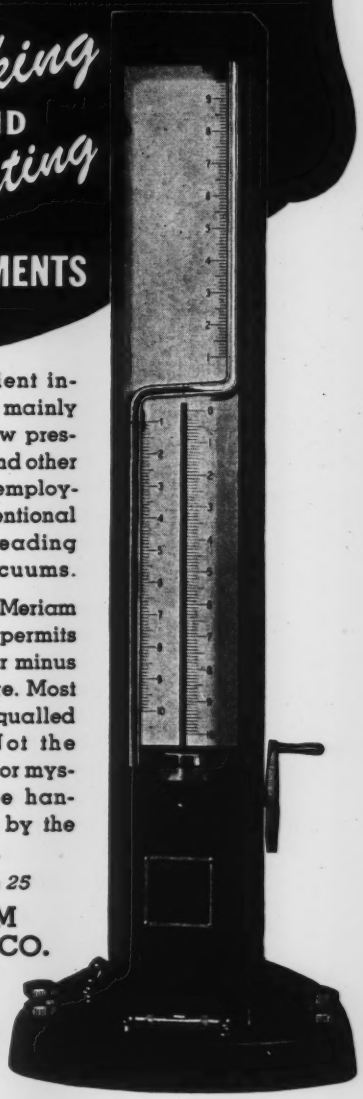

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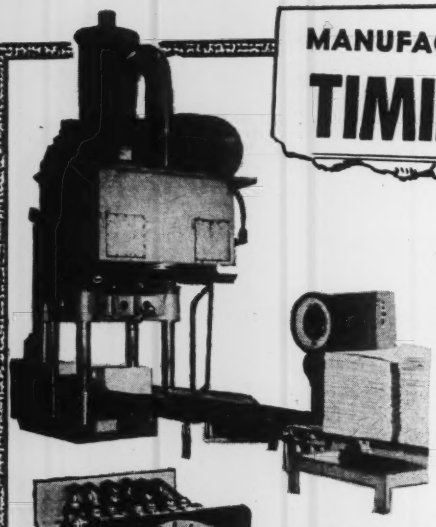

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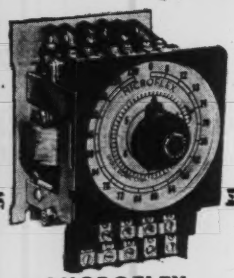

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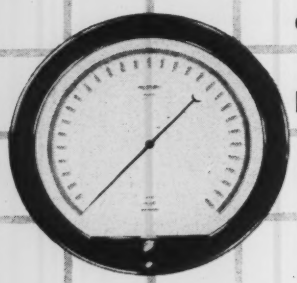

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May 22-23
"Electronics and Machines" Symposium, Professional Group on Industrial Electronics, Institute of Radio Engineers, Palmer House, Chicago. For information write Eugene Mittelmann, 549 W. Washington Blvd., Chicago 6, Ill.

May 22-24

American Society for Quality Control, Onondaga Memorial, Syracuse, N. Y. For information write W. R. Weaver, Gen. Chm., 1527 Republic Bldg., Cleveland 1, Ohio.

June 11-13

American Congress on Surveying and Mapping. Twelfth Annual Meeting and Exhibit.
Shoreham Hotel, Washington, D. C.
For information write Walter S. Dix, Ex. Sec., P. O. Box 470, Benjamin Franklin Station, Washington 4, D. C.

June 23-27

ASTM 50th Anniversary Meeting and 10th Exhibit of Testing Apparatus and Laboratory Supplies, Hotel Statler, New York, N. Y. For information write Robert J. Painter, Asst. Sec., American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Sept. 4-13
International Society of Photogrammetry, Shoreham Hotel, Washington D. C. For information write L. Ray Smart, U. S. Geological Survey, Trimetrogon Section, Washington 25, D. C.

Sept. 8-12

Instrument Society of America.
Seventh National Instrument Conference and Exhibit.
Public Auditorium, Cleveland, Ohio.

Sept. 29-Oct. 1

Eighth National Electronics Conference and Exhibition.
Sherman Hotel, Chicago.
For information write Karl Kramer, Ex. Sec., 852 E. 83rd St., Chicago 19.

October

Scientific Apparatus Makers Association.
Midyear Meeting of Recorder-Controller Section.
Seaview Country Club, Absecon, N. J.

Nov. 5-9

Scientific Apparatus Makers Association.
Midyear Meeting of Industrial Instrument, Laboratory Apparatus, Laboratory Equipment, Optical, Aeronautical, and Military Instruments Sections.
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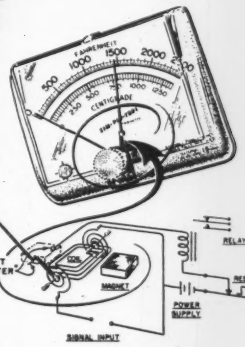

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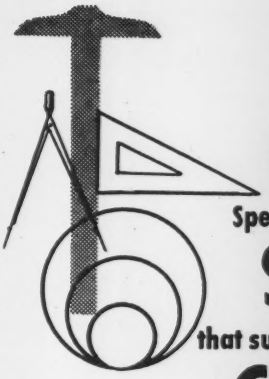

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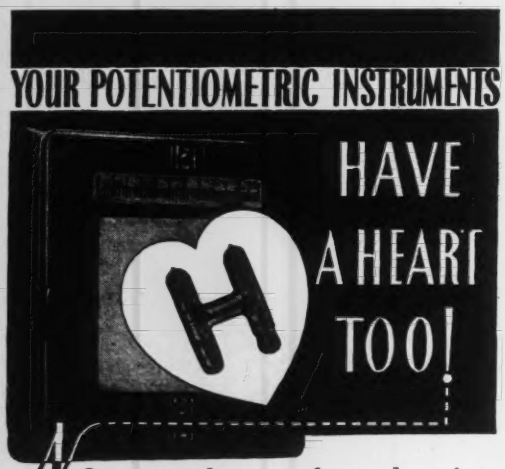

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INSTRUMENT ELECTRONICS

Continued from page 184

Rotary Conversion Equipment

The vibrator power supply changes a low-voltage d-c. source into a high-voltage d-c. supply. However, it can not handle more than 100 watts of power. For higher powers, rotary conversion equipment is used.

The *dynamotor* is a rotating d-c. machine consisting of a d-c. motor and d-c. generator. The motor is driven by the low-voltage d-c. source (battery or aircraft generator) and the generator produces the high-voltage d-c. output.

The *rotary converter* is a motor-generator which is driven by a.c. and which produces a d-c. output equal to the peak a-c. voltage. It is essentially a d-c. generator driven by an a-c. motor.

The *inverter* is a rotary converter except that a d-c. motor drives an a-c. generator. Hence the input is d.c. and the output is a.c.

TEST ITEMS FOR—VII. RECTIFICATION AND POWER SUPPLIES

7-1. The purpose of a power supply for an electronic circuit is to
(a) provide operating voltages
(b) provide signal voltages
(c) amplify weak signals
(d) rectify weak signals

7-2. The outputs of most power supplies are
(a) a.c. for both filament and plate circuits
(b) d.c. for both filament and plate circuits
(c) d.c. for filament and a.c. for plate circuits
(d) a.c. for filament and d.c. for plate circuits

7-3. Most power supplies for electronic circuits are
(a) batteries
(b) d-c. generators
(c) a-c. generators
(d) rectifier-type

7-4. A dual-purpose power transformer contains windings for several
(a) high voltages only
(b) low voltages only
(c) high and low voltages
(d) power supplies

7-5. A transformer winding with a center tap is useful for
(a) providing two voltages 90 degrees out of phase
(b) providing two voltages 180 degrees out of phase
(c) doubling the phase of a voltage
(d) doubling the frequency of a voltage

7-6. A rectifier is
(a) a diode only
(b) a triode only
(c) any device that conducts equally well in both directions
(d) any device that conducts better in one direction than in the reverse direction

7-7. The maximum voltage that can be developed across the load of a half-wave rectifier driven by a transformer equals
(a) the peak voltage developed across the transformer secondary
(b) the peak voltage developed across the secondary minus the drop across the rectifier
(c) half the peak voltage developed across the transformer secondary
(d) half the peak voltage developed across the secondary minus the drop across the rectifier.

7-8. A full-wave rectifier differs from a half-wave rectifier in that the former
(a) conducts on both half cycles of each cycle
(b) produces rectified pulses at a rate of 120 per sec.
(c) uses two rectifying elements
(d) all the above

7-9. The voltage developed across the load of a half-wave rectifier differs from that developed by a full-wave rectifier (with the same transformer) in that the former is
(a) larger
(b) pulsating
(c) smoother
(d) alternating

7-10. The most common rectifier-type power supply for electronic circuits is the
(a) single-phase half-wave rectifier
(b) single-phase full-wave rectifier
(c) 3-phase half-wave rectifier
(d) 3-phase full-wave rectifier

7-11. A 3-phase half-wave rectifier differs from a single-phase full-wave rectifier in that the output of the former
(a) has more ripple
(b) has a higher ripple frequency
(c) is more difficult to filter
(d) all the above

7-12. An advantage of a metallic-oxide rectifier over a diode rectifier is that the former
(a) requires no filament power
(b) has a lower reverse resistance
(c) is more efficient as a rectifier
(d) all the above

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7-13. An advantage of a bridge rectifier over a conventional full-wave rectifier is that the former
(a) requires no center-tapped transformer
(b) produces a higher output voltage with the same transformer
(c) has lower inverse voltage across each element
(d) all the above

7-14. A disadvantage of a voltage doubler is the
(a) low voltage output
(b) low current output
(c) need for four rectifying elements
(d) need for a center-tapped transformer

7-15. A disadvantage of the resistance-capacitance filter is that
(a) the capacitor has low impedance to a.c.
(b) the capacitor has high impedance to d.c.
(c) there is an IR drop across the resistor
(d) the resistor has less impedance to a.c. than the capacitor has

7-16. A choke is
(a) a filter inductance
(b) a filter capacitance
(c) a small orifice
(d) a small resistor

7-17. The basic principle on which filter capacitors operate is that the capacitor has
(a) low impedance to a.c. and high impedance to d.c.
(b) low impedance to d.c. and high impedance to a.c.
(c) low impedance to both d.c. and a.c.
(d) high impedance to both d.c. and a.c.

7-18. A filter inductor always is
(a) in series with a resistor
(b) in series with the current
(c) in parallel with a capacitor
(d) in parallel with the current

7-19. An inductor-input inductance-capacitance filter differs from a capacitor-input inductance-capacitance filter in that the former has
(a) more components
(b) higher output current
(c) higher output voltage
(d) better regulation

7-20. The regulation of a power supply refers to
(a) the maximum current output
(b) the maximum voltage output
(c) the change in voltage caused by current change
(d) the change in current caused by voltage change

7-21. A filter for a mercury-vapor rectifier should be
(a) a choke-input filter
(b) a capacitor-input filter
(c) a resistance-capacitance filter
(d) any of the above

7-22. An aircraft power-supply filter for an 800-cps. system differs from that for a 60-cps. system in that the components of the former
(a) require higher inductive reactance
(b) require lower capacitive reactance
(c) are smaller and lighter
(d) are more fragile and sensitive

7-23. An electronically-regulated power supply controls the output voltage by changing the
(a) resistance of a bleeder resistance
(b) plate resistance of a vacuum tube
(c) impedance of an inductance
(d) saturation of a choke

7-24. A vibrator supply is used when the source of energy is
(a) d.c.
(b) a.c.
(c) low voltage
(d) high voltage

7-25. A synchronous vibrator power-supply differs from a conventional vibrator power supply in that the former has
(a) a-c. input
(b) d-c. input
(c) no rectifier tube
(d) no filter

Design of Laboratory Apparatus

Continued from page 153

to come in the field of laboratory apparatus. It seems inevitable that instruments of increasing complexity will be required, and that many of these complex instruments will find their way into control and industrial laboratories. The apparatus manufacturer must be prepared not only to make these complex instruments, but to provide adequate and complete service, including training of operators and maintenance personnel, as well as the customary repair facilities.

Manpower

Manpower problems have influenced the development of laboratory apparatus in several ways. In times like these, when there is a shortage of technical personnel, laboratory instruments are needed which will increase the productivity of available personnel and thus alleviate the immediate distress caused by the manpower shortage. Competent scientific and technical personnel will likely be in short supply for several years at least. Estimates of the current shortage range from 25,000 to 85,000. College enrollment statistics and military service requirements offer little hope that the situation will improve rapidly. We may anticipate, therefore, a continuing interest in all types of laboratory apparatus which will carry out laboratory operations mechanically, thereby making available more of the worker's time

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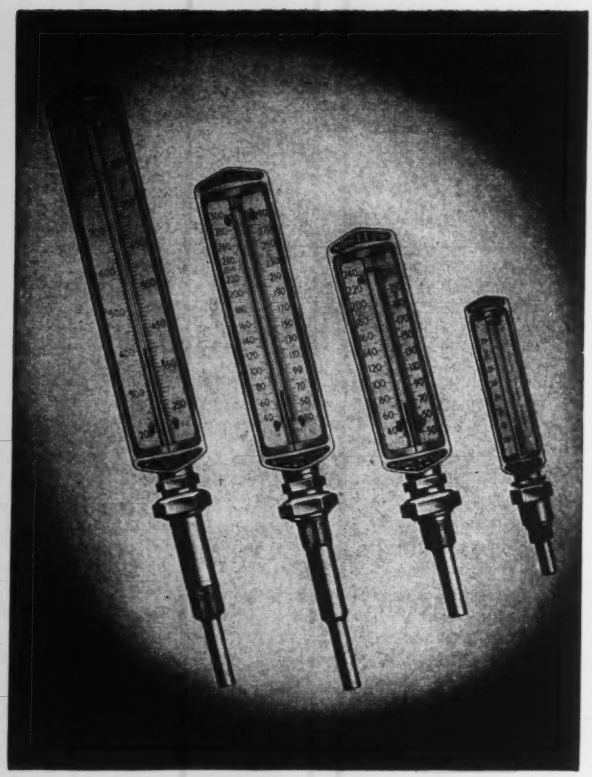

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for creative thought and for activities which cannot be performed mechanically. Increasing cost of labor is another manpower factor which has accelerated the development of laboratory apparatus. In some control laboratories, new time-saving techniques, involving new types of instruments, were evolved. In other cases apparatus was developed which performed automatically or semi-automatically operations previously carried out manually. Such equipment in the laboratory often paid for itself in a short time by the saving in labor costs alone. The biggest savings occur, of course, when automatic instrumentation is applied directly to process control in the plant, because labor cost of plant operators as well as laboratory workers is reduced. This fact, probably more than any other, accounts for the speed with which process-control instruments evolve from laboratory instruments.

A third aspect of manpower problems is human failure. Instruments do not tire or become careless. Being constantly alert is especially important where safety is involved, and in this respect instruments are indispensable. Safety considerations also encourage the development of remote sampling and remote indicating apparatus which make it unnecessary for personnel to enter hazardous areas to collect samples or to observe operating conditions.

Defense Activities

The defense program has influenced instrument development in several important ways. First, the money available for defense made it possible to undertake apparatus development projects which probably would not have been undertaken at all, and certainly not on the scale on which they were carried out under the pressure of war.

The tremendous nuclear program, which probably could never have been initiated by private enterprise in peacetime, has produced an entirely new type of laboratory, the so-called "hot-lab," which uses instruments such as Geiger and scintillation counters, scalers, etc. These instruments have already become standard equipment in many research laboratories, but the utilization of radioactive techniques is still in its infancy. The exponential increase during the past year in the sale of isotopes by Oak Ridge to scientific and industrial laboratories is a clear indication of what is to come.

Radiation apparatus and instruments will be needed not only in quantity but in variety. With respect to probes and other radiation-sensing apparatus, there is no forseeable limit to the variety which will be needed, ranging from microscopic units for medical research to massive units for continuous process control in the chemical or metallurgical industries. Opportunities for growth appear to be unlimited.

Another important aspect of the defense program is the effect which military specifications have had on conventional laboratory apparatus. Equipment, particularly electronic instruments used in the early part of World War II, often failed in the field because it was unsuited for the environmental and operating conditions to which it was subjected. Equipment going to the tropics was especially notorious. As a result of these failures, tropicalization treatments were devised which resulted in instruments which stand up under unfavorable conditions of the tropics. Although fungicidal coatings aided in this development, probably the most important development was hermetic sealing. Small electronic components were "potted" or sealed into airtight containers. O-rings and airtight gaskets became commonplace in instruments. Today this construction is used widely in ordinary instruments to protect delicate instrument parts from corrosive atmospheres, high humidity, and contamination. Military usage generated a need for ruggedness far beyond anything encountered in peacetime operations. Although the military specifications appeared to be unreasonable, we found that we could make instruments which met the specifications. I believe we are glad now that we were forced to build ruggedness, hermetic sealing, etc., into our instruments because these features are contributing to the utility of instruments in peacetime as well as in war.

Continued on page 222

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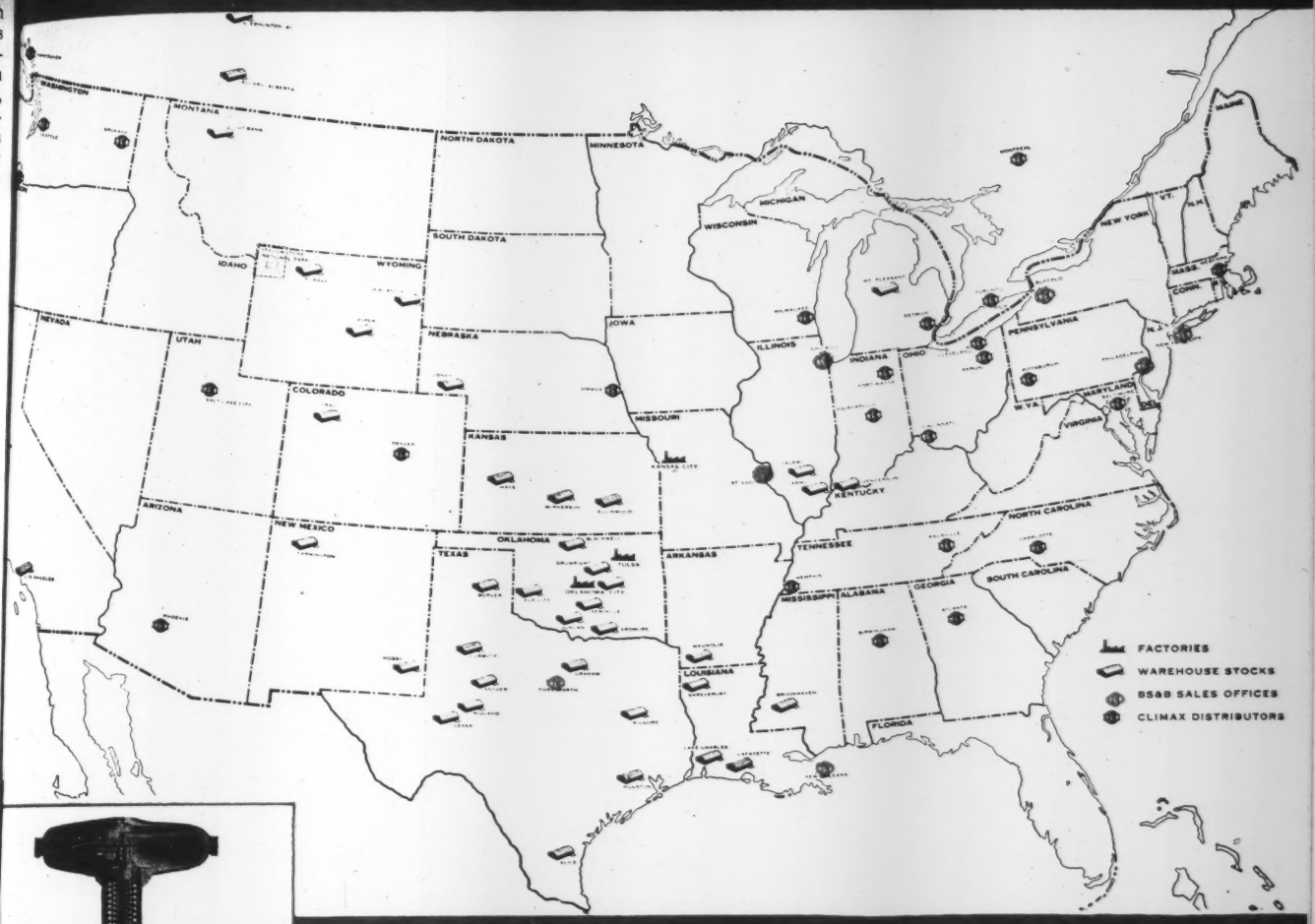

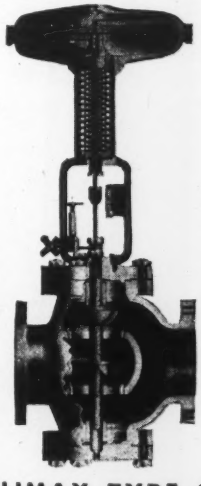

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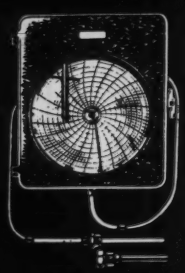

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TRENDS

Laboratory versus Industrial Apparatus

One significant trend is the elimination of the boundary between the fields of laboratory apparatus and industrial apparatus. Formerly the two fields were clearly distinct. This is no longer true. On the one hand, instruments which formerly were to be found only in laboratories, now are used widely in the plant. Even complicated instruments such as infrared and mass spectrometers are becoming commonplace industrial instruments. The speed with which laboratory equipment is transformed into industrial equipment often is surprising. Ten years ago few laboratories could boast of an infrared or a mass spectrometer. Today these instruments are to be found in virtually every petroleum refinery; modern refineries would find it difficult to operate efficiently without these instruments for process control. It may truthfully be said that *the laboratory instrument of today is the industrial instrument of tomorrow.* Conversely, we find rapidly increasing use in the laboratory of what were formerly considered industrial instruments. Recorders of all descriptions are now used for laboratory experiments. Laboratory directors are becoming increasingly aware of the fact that it is cheaper to buy a recording thermometer than to hire a Ph.D. to watch the mercury rise and fall in a glass thermometer, laboriously recording temperatures in his notebook.

There is a trend in industrial recorders toward smaller instruments. Uunquestionably the trend will contribute to the wider use of recording instruments in the laboratory. Designers of laboratory apparatus should keep in mind the potential dual usage of their apparatus and, wherever possible, design it so that it will be equally useful in the laboratory and in the plant.

Continuous Testing

Another trend is the replacement of the intermittent grab-sample method of testing by continuous testing. In many industries, critical process variables are continuously monitored. Instruments for the continuous monitoring of cellophane sheet, of the thickness of the tin coating of tin plate, of the acidity of waste liquors, etc., are typical examples. There is a well-recognized trend in industry toward continuous operation as opposed to batch operation; the same trend exists in the field of laboratory and industrial instruments.

Automatic Operation

The trend today is toward simplicity of knobs and controls. The number of manual adjustments is kept to a minimum, even at the expense of adding to the complexity of the internal mechanisms. Whereas formerly manual adjustments were provided to compensate for drift, circuits which provide automatic regulation are now incorporated in better instruments. The ultimate instrument is one which has merely an off-on switch, all operations of the instrument being entirely automatic.

Along with the increase in automatic operations has come increasing use of computing devices. A measuring instrument converts a change in some variable, such as chemical concentration or temperature, into a change in some physical quantity, such as electrical potential or current, which can be used to actuate a recording or indicating mechanism. The indicated value often does not bear a simple relation to the variable being measured. In modern instruments, circuits automatically do the computing and permit the operator to obtain his data in any desired form—linear, logarithmic, or reciprocal functions.

There has been much recent publicity in the news and in technical publications on the use of computers, of both the analog and digital types. One new development is an instrument which eliminates the tedious conversion of recorded curves into corresponding numerical data. This instrument, called an analog-digital data translator, automatically converts changes in instrument indications or in some variable, into corresponding digital values, which are automatically recorded on tape or punched cards for use in automatic digital computers. If desired, the data may be fed directly

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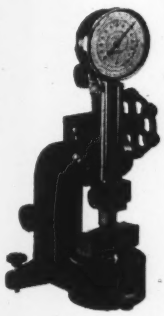

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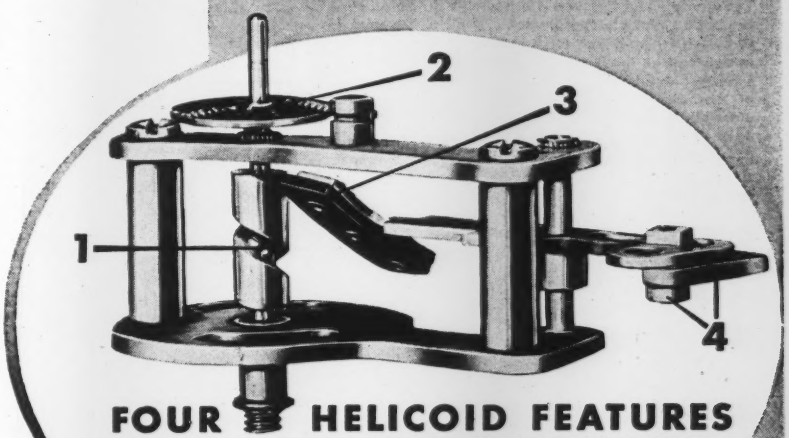

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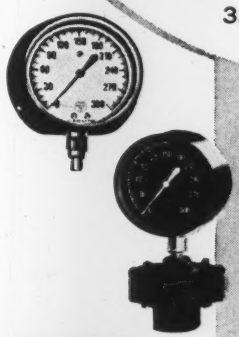

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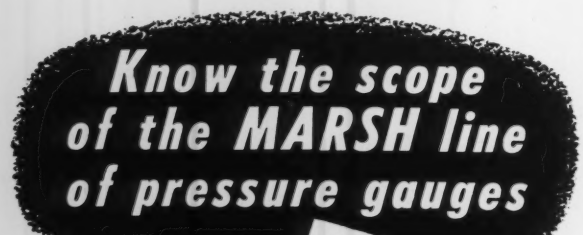

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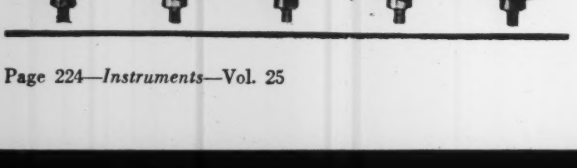

into digital computers. Instruments of this type unquestionably will find increasing use.

Use of New Physical Principles and Phenomena

To meet modern research and industrial requirements, instruments have been and are being developed which embody new or little-used physical phenomena and principles. Some such developments already in use include (1) magnetic susceptibility to determine the oxygen content of a gas, (2) optical spectrophotometry, from the far ultraviolet to the far infrared, (3) mass spectrometry, (4) electron diffraction, (5) polarimetry, (6) index of refraction, etc. A new type of radio-frequency mass spectrometer which does not require magnetic fields is now looming on the horizon. This instrument, because of its smaller size and presumably lower cost, gives promise of becoming a very valuable laboratory and industrial tool. Spectrophotometers, which measure the absorption or emission of radiation ranging from the far ultraviolet to the infrared are now in widespread use. The microwave region beyond the infrared is now being explored. The technique of spectrophotometry will be applied to the extreme ultraviolet, to X-rays, to β-rays, to fluorescence radiation, to polarimetry and to refraction. A relatively recent development, which is a revival of the pioneer work of Bunsen and Kirckhoff, is flame spectrophotometry. The full impact of flame spectrophotometry has not yet been felt, particularly in fields such as clinical diagnosis. This technique, which makes possible the rapid and inexpensive determination of some 40 elements in low concentrations and with only a few drops of sample, may revolutionize medical diagnostic procedures.

The rapid strides which have been made recently in protein chemistry are particularly significant. Electrophoretic diffusion apparatus, both of the analytical and of the preparative types, will become increasingly common as protein chemistry develops.

As the science of nuclear chemistry and physics adds to our knowledge of the nucleus, we must expect the development of apparatus dealing with nuclear phenomena and properties. Nuclear magnetic moment already is being seriously considered for use in chemical analysis.

Micro Methods

Micro analytical techniques, in many cases, have replaced macro methods, often with substantial savings in cost of reagents and time. Micro methods often are the only methods which can be applied where the available sample is small. The development of many of the new antibiotics, for example, would have been delayed greatly had it not been for the availability of micro techniques which permitted the determination of molecular structure from minute traces of biologic material. Trace amounts of elements and other substances have acquired new significance in the light of recent research in such fields as nutrition, medicine, agriculture, photography and air pollution. The next few years will see increasing use of monitoring apparatus which will continuously analyze the ambient atmosphere for traces of air pollutants.

Electronics

Electronics unquestionably has had a greater influence on the development and design of laboratory apparatus than has any other single factor. The almost unlimited versatility of electronic circuits which measure currents as low as 10^{-15} ampere, and which amplify feeble currents or small potentials to virtually any desired magnitude, have made it possible to devise instruments which would have been completely impossible without electronics. In passing, it is of interest to note that apparatus makers of this country have a big edge over European competitors in this respect. The great emphasis placed on electronics during the war and in the tremendous radio and television industry, has provided us with many advantages, such as thousands of skilled electronic engineers and a vast assortment of electronic components on which to draw for optimum instrument design. We are far more electronic-minded than are apparatus makers in other countries, a fact which is reflected in the design of our laboratory instruments.

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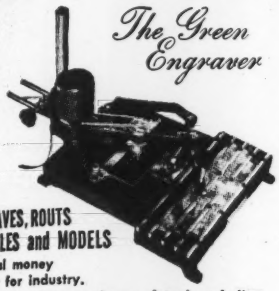

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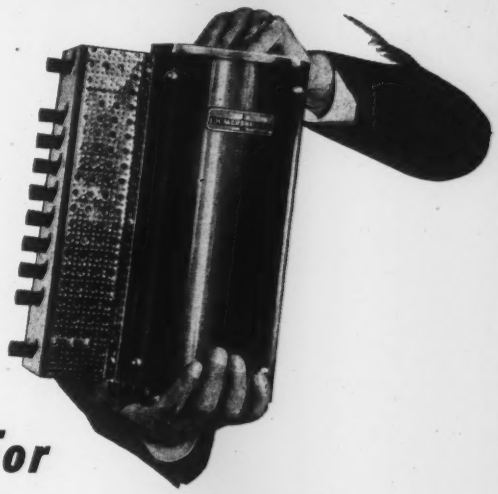
There is a marked trend in electronic instruments toward miniaturization. Electron tubes have gone from the older large bulbs to the miniature tubes and now to subminiature tubes which permit complete amplifiers to be built into a space no larger than a package of cigarettes. Even smaller tubes have been made but at this time, however, it appears likely that further miniaturization will be achieved through the use of transistors as a substitute for electron tubes. Transistors have many advantages, not only in size but also in reliability and freedom from maintenance problems because they eliminate the one big weakness of electronic tubes—the filament.

Miniaturization will bring about greater use of printed circuits. Today few laboratory instruments use printed circuits. With the availability of materials such as metal-coated plastics and the development of inexpensive techniques for printed circuitry, I believe that we will see printed circuits replace wired circuits in many laboratory instruments. We can expect laboratory instruments of the future to have their electronic components packaged in convenient, replaceable, hermetically-sealed plug-in-type units. If failure develops in the field, a skilled electronic engineer will not be required to repair the instrument. The user merely will plug in a replacement unit.

Design Trends

Not long ago the hallmark of a quality instrument was a beautiful polished-hardwood case. The wood case gave way to the black metal box in the early days of electronics. The early black boxes were unattractive, having sharp corners, exposed screws, and conventional black wrinkle finish. Rounded corners then appeared. Somewhat later the instruments went through what the industrial designer, Henry Dreyfus, called the "three-chromium-band period." More recently functional design has entered into the laboratory apparatus field; industrial design engineers are now an important part of the engineering staff of progressive apparatus makers.

Although an attractive appearance adds to the sales ap-



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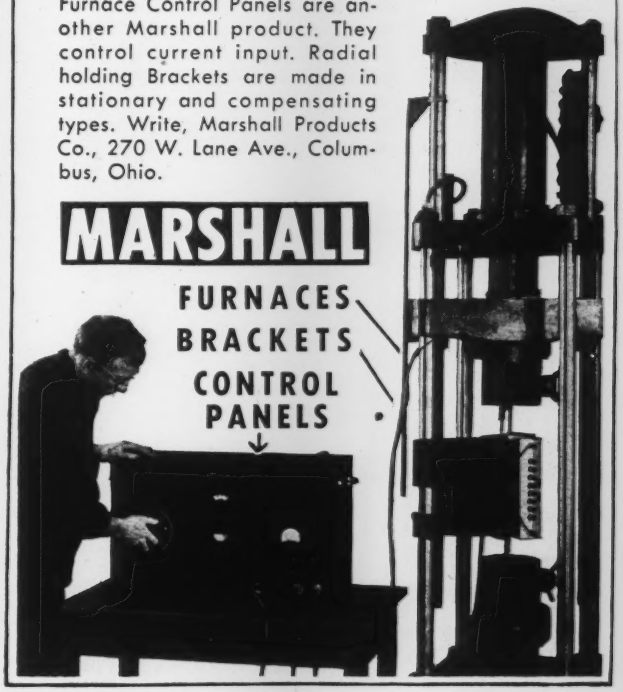

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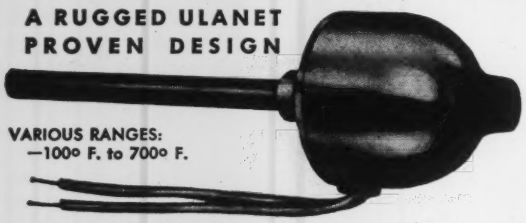

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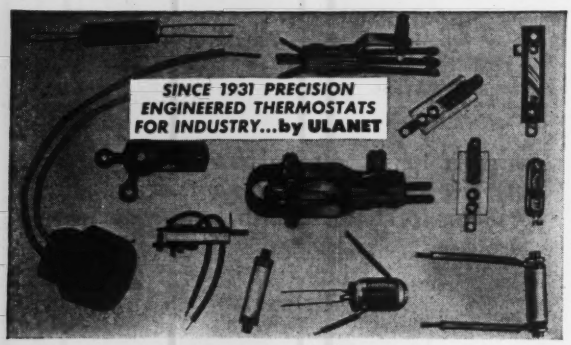

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peal of an instrument, the chief duty of the industrial design engineer is to contribute functional design. Functional design extends not only to appearance but to many essential constructional considerations, such as the placement of parts for convenient servicing, the location of controls for convenient use. Functional design usually calls for rounded corners and smooth surfaces. One of the factors responsible for smooth surfaces on instruments is that radiological instruments must have smooth easy-to-clean surfaces to avoid the accumulation of contaminating material. Wrinkle finishes are not satisfactory in this respect.

There have been developed new smooth, hard finishes which satisfactorily meet the requirements for radiological instruments. These finishes are used widely on other instruments. One big advantage of the wrinkle finish was that it covered cracks and scratches and required a minimum of surface preparation before painting. The hammertone finishes, which provide some of the advantages of the wrinkle finish and have a smooth surface, are becoming increasingly popular. Colorwise, the trend has been a change from the conventional black to gray, which probably will continue to be the most popular color for laboratory instruments.

Laboratory instruments of the future will incorporate many new design features which will contribute to their utility. Corrosion-resistant materials of construction will be used and critical parts will be hermetically sealed to better withstand the detrimental effects of laboratory and industrial environments.

Future apparatus will be designed for ease of maintenance. The newer instruments will incorporate self-checking features so that a simple procedure, such as moving a switch sequentially through few positions, will locate the cause of trouble. Self-checking features and unit packaging of electronic components will enable the operator to service his own instrument to a greater extent than is now possible.

Problems

Several problems will result from these trends. One is the changing role of the laboratory apparatus dealer. The rapid transformation of laboratory apparatus into apparatus for industrial process control will give rise to jurisdictional disputes between laboratory apparatus salesmen and industrial apparatus salesmen. The same jurisdictional disputes will extend to repair and installation services.

The increasing complexity of laboratory apparatus magnifies the problem of adequate repair facilities. Laboratory apparatus dealers will find it necessary to have skilled electronic repairmen on their staff and complete electronic test facilities. Manufacturers already have found it necessary to bring dealers' servicemen into their factories for specific training in the repair and servicing of their instruments. This trend of necessity must continue. Problems arise, therefore, as to division of responsibility and cost of training of such repairmen.

Another problem which may arise is the liability of the manufacturer for instrument failure. Although court cases where apparatus manufacturers have been sued for damages resulting from failure of their equipment are few indeed, increasing dependence on instruments may lead to such suits. Damages not only to plant equipment on product, but also death or injuries to personnel must be kept in mind by the instrument manufacturer and the serviceman. Manufacturers will attempt to protect themselves, of course, by appropriate liability insurance.

The real answer to the problem, however, is not insurance but sound design and construction of apparatus, and proper maintenance which will prevent accidents and will provide no basis for damage suits. Where the potential hazard justifies the added complication, especially with continuous monitoring, automatic self-checking features will be incorporated in instruments. These features will not only restandardize the instrument to maintain accuracy but will give adequate warning and possibly initiate emergency action in the event of an instrument failure.

As new instruments are being developed at a rapid pace, the manufacturer has the problem of deciding how much field testing is required before the instrument is released to the public.

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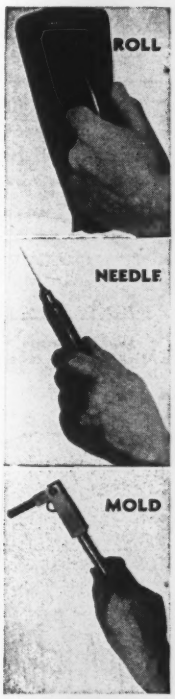

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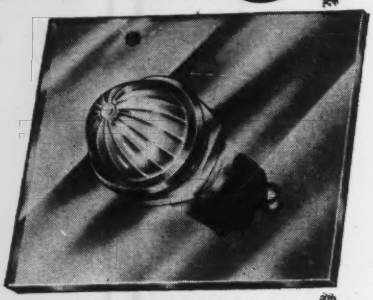

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Continued from page 193

first-order system produces a parabolic output function with a response delay and a dynamic error. If, for any reason, the actual input-output deviation is different from the deviation between the two curves shown in Fig. 15, F, this *deviation difference* may be considered as equivalent to a step function applied to the input at the particular moment. With a sectional parabolic curve, like that shown in Fig. 13c, deviation differences usually are introduced at the starting point of the hunting period. For this reason the output function resulting from an input function of this type can be considered as consisting of a parabolic curve section plus an exponential curve. The exponential corresponds to the response to the step function introduced at the starting point of the hunting period.

If the output hunting period is about six times longer than the characteristic time of the linear group, the exponential function would nearly die out after one-half an output hunting period, which corresponds to the optimum point. This means that only the parabolic portion remains in the output after the optimum point is passed. This parabolic portion of the output function is delayed by a time interval equivalent to the characteristic time of the output linear group, plus a dynamic error, as shown in Fig. 15, F.

Continued next month

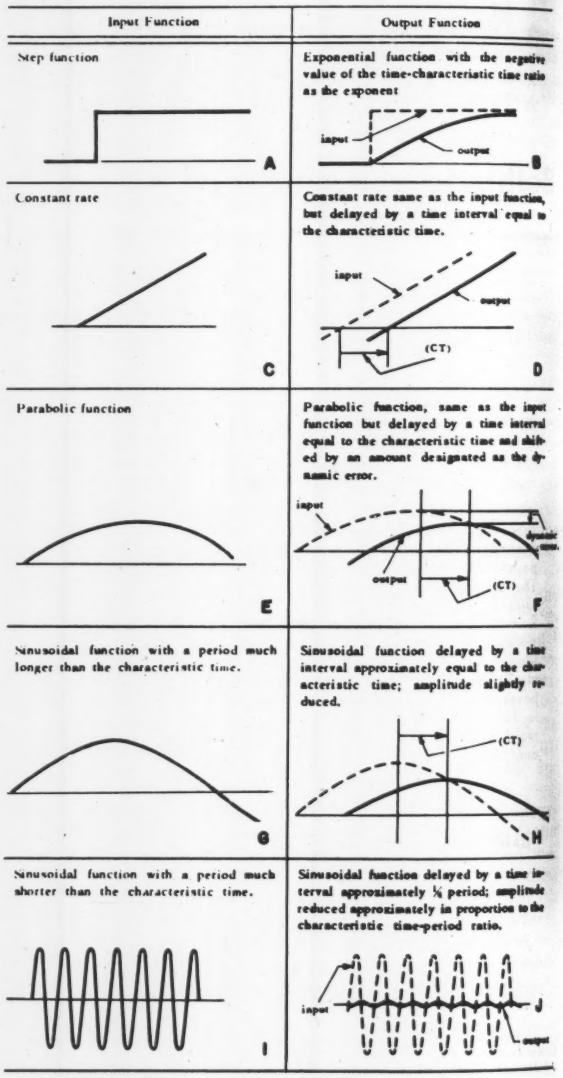
Input Function
Output Function
Step function
Exponential function with the negative value of the time-characteristic time ratio as the exponent
input
output
A
B
Constant rate
Constant rate same as the input function, but delayed by a time interval equal to the characteristic time.
input
output
(CT)
C
D
Parabolic function
Parabolic function, same as the input function but delayed by a time interval equal to the characteristic time and shifted by an amount designated as the dynamic error.
input
output
(CT)
E
F
Sinusoidal function with a period much longer than the characteristic time.
Sinusoidal function delayed by a time interval approximately equal to the characteristic time; amplitude slightly reduced.
(CT)
G
H
Sinusoidal function with a period much shorter than the characteristic time.
Sinusoidal function delayed by a time interval approximately ½ period; amplitude reduced approximately in proportion to the characteristic time-period ratio.
input
output
I
J

Fig. 15. Response of first-order systems to various input functions.

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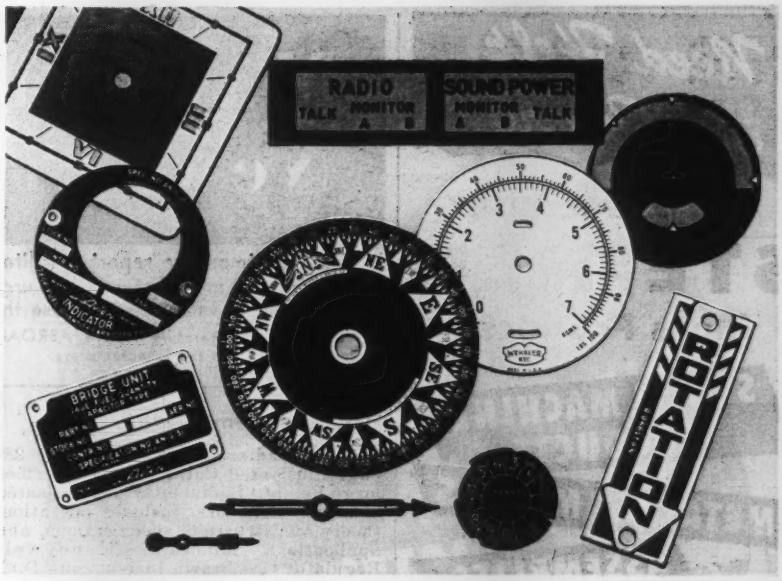

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Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

Temperature

U-94 **Radiamatic Pyrometers.** 28-page illustrated Catalog 9300 describes large line of "Radiamatic" compensated radiation detectors. Includes operation, theory, construction, specifications, and applications.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Sta. 40, Wayne and Windrim Aves., Phila. 44, Penna.

U-95 **Miniature Radiamatic.** 2-page illustrated Specification Sheet 83 gives specifications and dimensions of new "Miniature Radiamatic" radiation-detecting temperature-measuring device for use with Brown "ElectroniK" potentiometer.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Station 40, Wayne and Windrim Aves., Phila. 44, Penna.

U-96 **Miniature Thermostat.** 16-page leaflet "Who 'Stat?" tells cartoon-like story of miniature thermostat which weighs only 7.3 gms. and has height of 1.25 inches. Also lists products of maker's Instrument Division—relays, resistance bulbs, sealed thermostats, etc. —Thomas A. Edison, Inc., West Orange, N. J.

U-97 **Bimetal Thermostats.** 2-page illustrated Bulletin L-4609 describes new neoprene-protected bimetal thermostat. Includes principles, ratings, construction, and application data.—Stevens Mfg. Co., Inc., 69 S. Walnut St., Mansfield, O.

U-98 **Surface-temperature Thermometer.** 4-page news letter illustrates and describes maker's surface-temperature thermometer, rubber-hardness gage, industrial microscope, polar planimeter, and melting-point meters.—Clarkston Corp., 11921 W. Pico Blvd., Los Angeles 64, Calif.

Pressure

U-99 **Pressure Transducer.** 2-page Bulletin EM-1 gives description, specifications, dimensions, and frequency response of "Model BC-1" barium-titanate pressure-transducer.—Electromechanical Div., Atlantic Research Corp., 812 N. Fairfax St., Alexandria, Va.

U-100 **High-pressure Apparatus.** 12-page Vol. 8 No. 6 issue of "Aminco Laboratory News" features description of high-pressure vessels, valves, pilot plants, etc. Also microphotometer and other laboratory instruments.—American Instrument Co., Inc., 8030 Georgia Ave., Silver Spring, Md.

U-101 **Vacuum Gages.** 30-page Vol. 2 No. 1 issue of "Welch Physics and Chemistry Digest" contains digests of scientific articles and description of vacuum gages, balances, stirrer, grating spectrometer, and other laboratory instruments.—W. M. Welch Scientific Co., 1515 Sedgwick St., Chicago 10, Ill.

Weight

U-102 **Automatic Weighing.** 4-page illustrated Bulletin 0151 describes line of automatic weighing machinery for feed and flour industry, including scales, bagging, feeder-weighers, etc.—Richardson Scale Co., Clifton, N. J.

U-103 **Rice Scales.** 6-page Bulletin 0251 illustrates and describes large line of automatic scales designed for rice industry, including scales for shipping, receiving, milling, bagging, blending, etc. Also packer, counter, and bag-sewing conveyor.—Richardson Scale Co., Clifton, N. J.

Radioactivity

U-104 **Area Health Monitor.** 2-page

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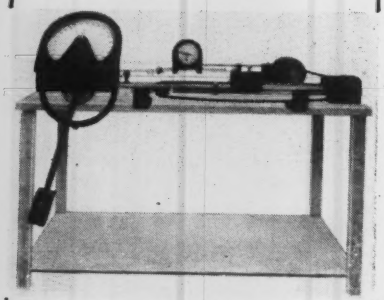

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NEW LITERATURE

Bulletin GEC-827 describes new equipment for indicating, integrating, totalizing, and telemetering gamma radiation.—General Electric Co., Schenectady 5, N. Y.

Process Controllers

U-105 **Industrial Instruments.** 28-page illustrated Catalog 5000 describes large and complete line of industrial instruments and related components. Includes specifications of 100 measuring and control instruments and valves plus new differential controller and "Tel-O-Set" controller family.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Sta. 40, Wayne and Windrim Aves., Phila. 44, Penna.

U-106 **Industrial Control System.** 6-page illustrated Data Release A-703 titled "Electronic Transmission and Control" explains new electronic "Autronic" principle for measuring and controlling process variables. Includes components and unit installation.—Swartwout Co., 18511 Euclid Ave., Cleveland 12, Ohio.

U-107 **Industrial Instrumentation.** 24-page brochure "Tomorrow is Today" gives pictorial story of diversity of instrument applications in industry and research.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Wayne & Windrim Aves., Phila. 44, Penna.

U-108 **Textile Instrumentation.** 28-page Bulletin 9306 discusses slasher-room instrumentation; benefits of measurement and control are discussed, and typical systems are presented.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Station 40, Wayne and Windrim Aves., Phila. 44, Penna.

U-109 **Oil Loader Controller.** 1-page Bulletin 156 describes new "R-416" remote panel-mounted oil loader for interchanging manual and automatic hydraulic control of turbines, etc.—Askania Regulator Co., 240 E. Ontario St., Chicago 11, Ill.

Combustion

U-110 **Flue-gas Analyzer.** 4-page illustrated Instrumentation Data Sheet 10.15-3a describes "Davis" thermal-conductivity flue-gas analyzer in combination with "Brown ElectroniK" recorder. Includes principles, features, and operation.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Sta. 40, Wayne and Windrim Aves., Phila. 44, Penna.

U-111 **CO_2 Recorder.** 12-page illustrated Bulletin 51-1008 describes "Condu-Therm CO_2 recorder. Covers principles, features, and operation of analyzing and recording units. Also gas sampling systems.—The Hays Corp., Michigan City, Ind.

U-112 **CO_2 Analyzer.** 5-page illustrated brochure contains principle of infrared measurement in "Liston CO_2 Analyzer," and typical response curves for various applications.—Liston-Becker Instrument Co., 20 Beckley Ave., Stamford, Conn.

Water Level

U-113 **Water-level Alarm.** 4-page illustrated Bulletin 493 covers operation, installation, and specifications on "Hi-

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U-114 **Liquid-level Telemetering.** 8-page illustrated "Hydrocorder Brochure" describes principles and operation of maker's liquid-level detector and 2-way r-f. telemetering system for flood control and industrial applications. —Raymond Rosen Engineering Products, Inc., 32nd & Walnut Sts., Phila. 4, Penna.

Optical

U-115 **Microscope.** 24-page illustrated book "The Theory of The Microscope" covers optical principles of microscopes, eyepieces, condensers, and phase-contrast microscopy.—Bausch & Lomb Optical Co., Rochester 2, N. Y.

U-116 **Surveying Instruments.** 156-page 52nd edition of "Manual of Surveying Instruments" includes care and handling of transits, levels, alidades, compasses, and accessory surveying equipment. Also theory and application of Beaman Stadia Arc, reticles, stadia readings, etc. Price is $1.00.—W. & L. E. Gurley, Troy, N. Y.

U-117 **Film Processing Tank.** 4-page brochure describes new "K-G Auto-Tank" for automatic, controlled film-processing; covers features, applications.—Auto-Tank Mfg. & Eng. Co., Inc., 3315 16th St., N.W., Washington 10, D. C.

Chemical Laboratory

U-118 **pH Indicator.** 8-page illustrated Folder EM9-96(1) describes new stabilized line-operated pH indicator. Includes features, ranges, specifications. —Leeds & Northrup Co., 4907 Stenton Ave., Phila. 44, Penna.

U-119 **Constant-temperature Bath.** 4-page brochure illustrates and describes "Model 111-MS" constant-temperature automatically controlled bath for viscosities, densities, refractive index, etc. Includes features and specifications.—Scientific Development Co., Box 795, State College, Penna.

U-120 **Boiling-point Recorders.** 1-page folder describes instrument for recording initial boiling point of light hydrocarbons (gasoline, solvents, etc.) for control of product quality. Includes principle.—Technical Instrument Laboratory, 3408 W. Slauson Ave., Los Angeles 43, Calif.

U-121 **Gas Analysis.** 4-page No. 12 issue of "Engelhard Industries News-Letter" features articles on thermal-conductivity gas-analysis cells, optical-quality quartz apparatus, rolled gold on stainless steel, etc.—Engelhard Industries, 113 Astor St., Newark 5, N. J.

U-122 **Boiling-point Conversion Chart.** 10 x 16 in. 1952 calendar contains dramatic picture of "ADL Collins Helium Cryostat" and conversion chart of gas boiling-points.—Arthur D. Little, Inc., 30 Memorial Dr., Cambridge 42, Mass.

U-123 **Flame Photometer.** 4-page illustrated brochure describes principle and specifications of "The Barclay" flame photometer for rapid quantitative analysis of sodium and potassium.—General Scientific Co., 3011 Dixwell Ave., Hamden 14, Conn.

U-124 **Refractometers.** 1-page Bulletin 514005 illustrates Japanese-made "Abbe," hand sugar, and hand protein

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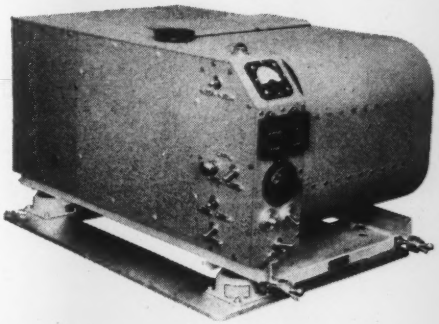

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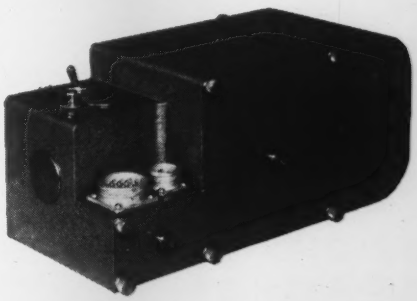
MODEL 409 OSCILLOGRAPH



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NEW LITERATURE

refractometers.—Electro-Physics Co., 287 Broadway, New York 7, N. Y.

Chemical Process Analysis

U-125 **Spectrometer.** 2-page Instrumentation Data Sheet 10.16-4a describes new mobile "Perkin-Elmer" infrared spectrometer utilizing "Brown Electronik" recorder. Includes operation, construction, and applicability.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Station 40, Wayne and Windrim Aves., Phila. 44, Penna.

U-126 **Spectrophotometer.** 2-page Folder C9-1051 illustrates and describes new rapid-scanning spectrophotometer with reflection attachment. Includes principles and features.—American Optical Co., Buffalo 15, N. Y.

U-127 **Spectroscopy.** 4-page Vol. 4 No. 5 issue of "Spectrographer's Newsletter" features illustrated article on new "Model 9300" Raman source unit.—Applied Research Laboratories, 4336 San Fernando Rd., Glendale 4, Calif.

U-128 **Chemical-research Consultants.** 4-page brochure illustrates and describes facilities of consulting firm for instrumentation, combustion, process development, organic research, program evaluation, and new chemicals.—Atlantic Research Corp., 812 N. Fairfax St., Alexandria, Va.

U-129 **X-ray Diffraction.** 8-page booklet "What is X-ray Diffraction" alerts industry to diverse uses of diffraction equipment for materials analysis.—North American Philips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y.

Inspection and Testing

U-130 **Testing Machine.** 4-page illustrated Bulletin 336 describes new "Baldwin Sonntag Model 12-H Universal Testing Machine" of 12,000 lbs. capacity. Includes design, operation, and specifications.—Testing Equipment Dept., Baldwin-Lima-Hamilton Corp., Phila. 42, Penna.

U-131 **Testing Machines.** 32-page Catalog RU-7-52 covers maker's hydraulic universal testing machines. Contains illustrations, specifications, and operating details on machines with capacities to 400,000 lbs.—Riehle Testing Machines Div., American Mach. and Metals, Inc., E. Moline, Ill.

U-132 **Electronic Gage.** 4-page Bulletin 103-11-51-5 describes and illustrates "Par-Ac" electronic production gage. Includes features, specifications, and accessories.—Graham-Mintel Instrument Co., 735 Carnegie Ave., Cleveland 15, Ohio.

U-133 **Electronic Microcomparator.** 4-page Bulletin 102 illustrates and describes new "Micro-Ac" microcomparator for checking dimensions to millionths. Includes features and specifications.—Graham-Mintel Instrument Co., 735 Carnegie Ave., Cleveland 15, Ohio.

U-134 **Cam Rise Gage.** 2-page Bulletin 1051-50 illustrates and describes new "Optical Cam Rise Gage" for measuring cam contours. Also optical dividing head for positioning camshafts.—F. T. Griswold Mfg. Co., 305 W. Lancaster Ave., Wayne, Penna.

U-135 **Abrasion Tester.** 6-page Bulletin 5003 illustrates and describes "Model 140" standard testing set for measuring abrasion resistance of sur-

faces.—Taber Instrument Corp., 111 Goundry St., N. Tonawanda, N. Y.

U-136 **Abrasion Testing.** 6-page illustrated Bulletin 5105 describes specimen holders used with abrasion-testing equipment.—Taber Instrument Corp., 111 Goundry St., N. Tonawanda, N. Y.

U-137 **Shock Testing.** 4-page bulletin is reprint of illustrated article "Instrument Shock Testing Theory and Measurement" by D. C. Kennard, Jr. of Air Materiel Command.—Haines Designed Products Corp., 117 N. Findlay St., Dayton 3, Ohio.

Valves & Tubing

U-138 **Air-operated Butterfly valves.** 12-page Catalog No. 1700 covers use of "Honeywell Air-O-Motor Diaphragm Operators" with "Continental Butterfly Valves." Includes specifications, ratings, and selecting information.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Station 40, Wayne and Windrim Aves., Phila. 44, Penna.

U-139 **Adjustable Port Valves.** 12-page Catalog No. 1800 covers use of "Honeywell Air-O-Motor Diaphragm Operators" with "North American Adjustable Port Valves." Data covers valves for gas, air, oil, steam, and water regulation.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Station 40, Phila. 44, Penna.

U-140 **Regulator Valves.** 4-page Bulletin 700 features principles and operation of maker's line of pilot-operated temperature- and pressure-regulating valves.—Spence Engineering Co., Inc., Walden, N. Y.

U-141 **Seamless Tubing.** 4-page catalog covers complete line of fine seamless tubing available in sizes from .010 to 5/8 in. O.D. in various metals. Includes facilities, tubing specifications, "pointer" tubing, and manufacturing operations.—Uniform Tubes, Level Rd., Collegeville 2, Penna.

U-142 **Tube Fittings.** 76-page Catalog 4300 contains complete data on tube fittings and tube-to-pipe adapters, fabricating equipment, selection, and installation. Includes use of flared fittings, flareless fittings, tubing, and tools. Also selection charts.—The Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.

U-143 **Sight-flow Indicators.** 2-page bulletin describes "Trin-vue" sight-flow indicators for checking flow of fluid in pipes. Contains specifications and ratings.—Trinity Equip. Corp., 472 Westfield Ave., East, Roselle Park, N. J.

Servosystems

U-144 **Servoamplifier System.** 4-page Instrumentation Data Sheet 10.20-4 describes and illustrates new "Brown 40X" high-gain servoamplifier system which drives motor from signals as low as 0.05 microvolt. Includes application, operation, and design.—Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Station 40, Wayne and Windrim Aves., Phila. 44, Penna.

U-145 **Servoamplifier.** 4-page Instrumentation Data Sheet No. 10.20-3 illustrates and describes maker's high-sensitivity low-stray-level servoamplifier system for converting small electric signals into directional motion.—Industrial Div., Minneapolis-Honeywell Regulator Co., Phila. 44, Penna.

U-146 **Servoamplifiers.** 4-page illustrated bulletins describe new "Models

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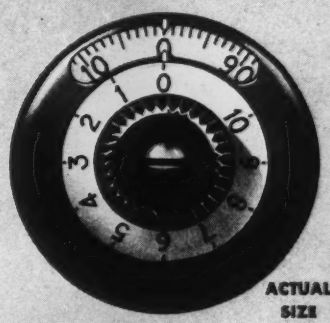

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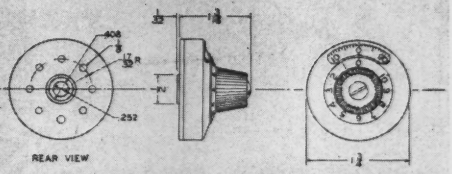

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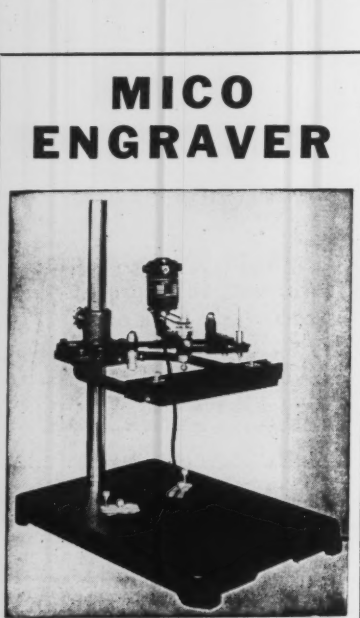

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U-147 **Servosystem Components.** 24-page illustrated catalog covers maker's line of gears, dials, speed reducers, limit stops, and other components useful for breadboarding servosystems.—Belock Instrument Corp., 181 Lawrence St., New Hyde Park, N. Y.

Electrical and Electronic Instruments

U-148 **Megohmmeter.** 10-page Vol. 26 No. 6 issue of "The General Radio Experimenter" illustrates and describes new megohmmeter "Type 1862-A" which measures from 0.5 megohm to 2,000,000 megohms; also high-power toroidal output transformer.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-149 **Ohmmeter.** 4-page Bulletin 24-46-28 illustrates and describes "Megger" low-resistance ohmmeters. Includes operating instructions and specifications.—James G. Biddle Co., 1316 Arch St., Phila. 7, Penna.

U-150 **Insulation Testing.** 6-page Vol. 7 No. 3 issue of "Biddle Instrument News" features article on interpretation of "Megger" tests on insulation resistance. New low-resistance ohmmeter is described.—James G. Biddle Co., 1316 Arch St., Phila. 7, Penna.

U-151 **Resistance-measurements.** 4-page folder illustrates and describes maker's instruments for insulation resistance, ground resistance, and psychological reaction. Also a-c. voltammeter, tachometer, and phase-sequence indicator.—Associated Research Inc., 3758 W. Belmont Ave., Chicago 18, Ill.

U-152 **VTVM.** 2-page bulletin includes features and specifications of "Model 215" vacuum-tube voltmeter and "Model 450" volt-ohm-milliammeter.—The Hickok Electrical Instrument Co., 10519 Du Pont Ave., Cleveland 8, Ohio.

U-153 **SHF Signal Generators.** 4-page Vol. 3 No. 2 issue of "hp Journal" features description of "Models 623B and 624A SHF Signal Generators" which also measure power levels and external frequencies.—Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

U-154 **Oscillography.** 220-page illustrated (8th edition) of "A Catalog of Equipment for Oscillography" covers maker's large line of cathode-ray-tube equipment. Includes oscillographs, recording equipment, design, specification interpretation, pattern interpretation, screen characteristics, etc.—Instrument Div., Allen B. Du Mont Laboratories, Inc., 1000 Main Ave., Clifton, N. J.

U-155 **Watthour Meters.** 16-page illustrated Bulletin GEA-5727 "10 Ways That I-50 Watthour Meters Reduce Operating Expenses" outlines possible savings that can be realized by utilities through use of "G-E I-50" watthour meters.—General Electric Co., Schenectady 5, N. Y.

U-156 **Electronic Test Instruments.** 4-page illustrated bulletins cover maker's line of test instruments, including signal generators from 85 kc. to 400 Mc., slotted line, VSWR indicator, and

VHF-UHF r-f. wattmeter.—The Rollin Co., 2070 N. Fair Oaks Ave., Pasadena 3, Calif.

U-157 **Electric Noise Generator.** 12-page Vol. 26 No. 7 issue of "The General Radio Experimenter" features illustrated article on "Type 1390-A Random-noise Generator" which uses gas-discharge tube as noise source. Also "Type 700-P1 Voltage Divider."—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-158 **Noise Measurement.** 8-page Vol. 26, No. 4 issue of "The Experimenter" features illustrated article "An Octave-band Analyzer for Noise Measurements." Includes specifications.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-159 **D-c. Power Supplies.** 16-page Catalog E 651 illustrates and describes maker's line of "Nobatrons" d-c. power supplies for from 3 to 300 volts at many currents. Includes principles and applications.—Sorensen & Co., Inc., 375 Fairfield Ave., Stamford, Conn.

U-160 **Regulated Power Supplies.** 4-page illustrated Bulletin 52A covers features and specifications of maker's "Models A3 and A3A" regulated power supplies with 4 outputs. 2-page Bulletin 53A covers "Model D6" heavy-duty supply.—Oregon Electronics, 2232 E. Burnside St., Portland 15, Ore.

U-161 **Power-supply Panels.** 13-page brochure illustrates and describes line of laboratory and test panels with various d-c. and a-c. outputs.—Electrosig Corp., P.O. Box 113, Buffalo 21, N. Y.

U-162 **Graphic Recorders.** 16-page booklet "Solving Industrial Crimes" covers applications of maker's graphic instruments for recording power, electric quantities, speed, resistance, time, pressure, and others.—The Esterline-Angus Co., Inc., P.O. Box 596, Indianapolis 6, Ind.

U-163 **Telemetering.** 44-page illustrated "General Telemetering Brochure" contains principles and operation of maker's line of multi-channel r-f. telemetering systems. Includes facilities of manufacturer.—Raymond Rosen Engineering Products, Inc., 32nd & Walnut Sts., Phila. 4, Penna.

U-164 **Electronic Shaft-position Indicator.** 4-page bulletin illustrates and describes new electromechanical shaft-monitor system for indicating position of rotating shaft. Covers operation, accuracy, construction, characteristics.—Engineering Research Associates, Inc., 1902 W. Minnehaha Ave., St. Paul, Minn.

U-165 **R-C Circuits.** 24-page Vol. 16, No. 11 issue of "The C-D Capacitor" features illustrated article on "Prac-

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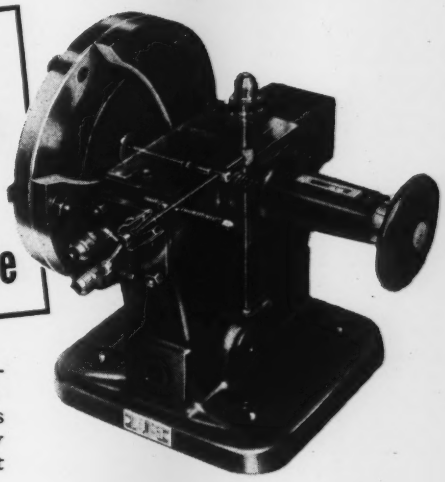

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tical R-C Circuits." Includes "The Radio Trading Post" section.—Cornell-Dubilier Electric Corp., Hamilton Blvd., S. Plainfield, N. J.

U-166 **TV Servicing.** 48-page book "TV Servicing" (Form TVS-1030) is collection of articles containing analysis of servicing problems. Includes alignment, troubleshooting, and circuit analysis. Price 35c.—Commercial Engineering, RCA Tube Dept., Harrison, N. J.

Electrical and Electronic Components

U-167 **Electronic Components.** 6-page Vol. 2 No. 1 issue of "Mr. Fed" contains news features and description of distributor's nation-wide facilities for supplying electronic components and instruments of any type and in any quantity.—Federated Purchaser, Inc., 114 Hudson St., Newark 4, N. J.

U-168 **Resistors and Pot-rheostats.** 16-page illustrated Catalog 51 covers large line of resistors, controls, switches, attenuators, tube-type resistors and ballasts, line-voltage regulators, rheostats, glass-insulated flexible resistors, and others.—Clarostat Mfg. Co., Inc., Dover, N. H.

U-169 **Resistors.** 2-page Nov.-Dec. '51 issue of "The Ohmite News" describes fixed wire-wound resistors and heat-control rheostats. Also new "Ohm's-law Calculator."—Ohmite Mfg. Co., 4835 Flournoy St., Chicago 44, Ill.

U-170 **Printed-circuit Materials.** 2-page bulletin lists line of resistor, conductor, and shielding parts for printed circuits. Includes ranges, uses, application factors, and durability.—Micro-Circuits Co., New Buffalo, Mich.

U-171 **Capacitors.** 28-page Catalog 200C is comprehensive catalog of large line of capacitors, including molded plastic, metalized, ceramic disk, electrolytic, tiny paper, oil, and mica. Also feed-through and resonant filters.—Cornell-Dubilier Electric Corp., Jobber Div., S. Plainfield, N. J.

U-172 **Pot-rheostat.** 1-page illustrated Bulletin 20 covers features and specifications of "Model SR" subminiature wire-wound potentiometer-rheostat.—Standard Electronics Mfg. Co., 8617 W. 3rd, Los Angeles 48, Calif.

U-173 **Transformers.** 1-page Output-transformer Chart 375 lists 129 frequently used output transformers and associated tubes. Chart lists tubes, use, class, watts, load resistance, and the correct output transformer.—Standard Transformer Corp., 3580 Elston Ave., Chicago 18, Ill.

U-174 **Preferred Tube Types.** 4-page folder PTL-501B/9-51 contains list of recommended electron tubes for new-equipment design. Includes miniatures, phototubes, ignitrons, etc.—Commercial Engineering, RCA Tube Dept., Harrison, N. J.

U-175 **Electronic Tubes.** 2-page discount chart for electron tube prices describes distributors facilities for supplying more than 3000 tube types.—State Labs, Inc., 37 E. 28th St., New York 16, N. Y.

U-176 **Oscillograph Tube.** 4-page illustrated Bulletin 16ADP7-10-51 contains tentative specifications of new "16ADP7" 16-in. oscillograph tube.—Tube Dept., Radio Corp. of America, Harrison, N. J.

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